BME Design-Spring 2021 - Josh Zembles
Complete Notebook

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Josh Zembles

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Team contact Information

Sara Wagers - Dec 08, 2020, 11:04 PM CST

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Project description

Sara Wagers - Mar 03, 2021, 1:08 PM CST

Course Number:

402

Project Name:

Microfluidic Cell Sorter

Short Name:

Cell Sorter

Project description/problem statement:

The Skala lab has developed label-free optical signals to sort T-cells by activation state. The next step in their research requires a microfluidic chip to flow the cells at speeds that allow 100's of ms integration time on the detector. The device can be commercial or newly designed, and requires a number of specifications in order to integrate with their system. The function of the device should create single-file cell flow through the interrogation window with a stable core diameter of 20 um to 50 um while ensuring that stability is first maintained in the z direction. Cells should flow through the microfluidic device along with a PBS sheath fluid at a flow speed of 1 mm/s and up to 10x faster.

About the client:

Dr. Melissa Skala works out of the Skala Lab which is associated with the Morgridge Institute for Research. The lab is known for photonics based technologies which they use to discover cancer solutions. Quality control of T-cell and stem cell therapies plays a large roll in this research. Emmanuel Contreras Guzman and Kayvan Simimi were designated from the lab to aid in the improvement of the T-cell sorting mechanism and are the main side contacts of the project.

2021/2/9 - Client Meeting 1

Sara Wagers - Mar 03, 2021, 12:53 PM CST

Title: 2/9/21 Client Meeting

Date: 2/9/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Skala, Emmanuel

Goals: touch base about goals for the semester and next steps

Content:

- thoughts from emmanuel and Kayvan
    - Determine some outlet parameters at a range of pressures
        - Vary sheath and inlet pressures?
            - Fix inlet pressure and vary the sheath
                - Sweep across pressures

- Inertial design
    - Change the channel diameters (but square channel) and then do a sweep of different pressures for each of those
    - Probably fix the number of turns for now
- Work on both designs since we have the designs already
- Look at that paper again to fix the focusing issues
    - Iteration to get the focusing down first before even looking at these parameters
    - Square channel
    - Number of turns needed depends on the pressure
        - 1 millibar to 1000 millibar is what their pump can do
    - Doesn’t know if there is a way to get quantitative info about the focusing
        - About 5 micron tolerance, deviation from the center of the focus
        - Just look qualitatively first
        - This should come from the turn radii and the sizes of the channel

- What they’ve been doing
    - Working on the inertial design
        - Would be good to see some simulations from the cone design

Conclusions/action items:

Send melissa the poster again

Get qualitative info on the focusing

Widen the exit of the inertial design to be the same as the width of the channel

- Do 50 - 100 micron mirrored turns

Meetings monday at 4 starting on the 22nd

Ask her next week if that still works

2021/2/22 - Client Meeting 2

Sara Wagers - Mar 03, 2021, 12:54 PM CST

Title: 2/22/21 Client Meeting

Date: 2/22/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Skala, Emmanuel

Goals: touch base about progress and next steps

Content:

- Josh's funnel issues
    - Set inlet pressure to 1 millibar
        - Resulted in a very high outlet velocity
        - Worth looking at because they may be able to flow faster
            - New laser!!

Compare the two designs

- So it is ok that joshs is too fast?
- Just make sure to keep the same pressures so that we can compare them

Snake/Inertial design

- 100 and 150 micron done?
- May have misdefined some parameters
- Looks like it is doing some focusing
    - Increase the turns to make the focus even more confined
- More turns?
    - Emmanuel's longest was something like 100 turns to get enough focusing
    - Use the linear pattern to make more turns
- Width of the channel
    - Changes but alternates consistently
    - Look at the paper again
        - Copy what they do

2021/3/1 - Client Meeting 3

Sara Wagers - Mar 03, 2021, 12:57 PM CST

Title: 3/1/21 Client Meeting

Date: 3/1/**21**

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Skala, Emmanuel

Goals: touch base about goals for the semester and next steps

Content:

- Work on the snake design
    - Seems to be focusing!
    - Gets down to velocity of 1 mm/s
    - Simulations are taking a long time to run with these new designs
- Now vary the pressure using a particle study
    - From 100 millibar to 1000 millibar
        - Pump maxes out at 1000 millibar
        - Do a **parametric study** maybe at every 10 or 20
            - Look this up so we don't have to do it individually
        - And then the 3 channel widths
    - Goal to make velocity as low as possible but would still like to see how it changes with these pressures.
    - Also try to see how confined the particles are if we can
        - Cross section view???
            - Look into how we can do this

Other design

- **Last week we talked about using it as a comparison of pressures?**
    - **The velocity was really high**
        - **1 millibar isn't a super high pressure so it seems off**
- **Run some more simulations on it**
    - **Varying the sheath fluid and inlet pressures**
        - **Look at core outlet velocity**
- **We can pull it up next time and take a look at what is going on**
    - **Also look at what the dimensions are**

- **We will keep playing with the dimensions and see how that affects it**

2021/3/15 - Client Meeting 4

Sara Wagers - Apr 25, 2021, 4:28 PM CDT

Title: 3/15/21 Client Meeting

Date: 3/15/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Skala, Emmanuel

Goals: touch base about goals for the semester and next steps

Content:

- Update
    - Josh with the funnel
        - Messing around to try to reduce the outlet speed
        - Haven't been able to get the speed down
            - Even with both of them down at the 1 millibar
            - Can we see the distribution of the flows across the cross section of the funnel
                - Have some pictures of this ready for the next meeting or throw it in the slack channel
            - Emmanuel still wants us to get a sense of how the design is changing with different pressures
                - So still keep the radius constant and vary pressure to look at the range of outlet velocities
                    - Valuable even if it won’t work for the current setup
                - Do a 3D plot of some sort to look at how the change of the pressure will affect the velocity
                    - Inlet pressure vs. core flow velocity vs. diameter

Add more pressures to the snake graphs

For next time:

Pictures of the cross section for velocity of funnel

Snake Data

- Linear relationship between pressure and the resulting particle velocity at the lower pressures (might change at higher pressures?)
    - May be good to add some more points between 50 and 100 and then up to 1000 too
        - Trying to minimize velocity but moving forward on this project it will be useful for them to know what the pump can do overall
    - Wants to see the different parameters on the same plot?
        - So velocity, focusing, etc vs pressure for the range of the pump
- Try to do the particle study (parametric)
    - Should be able to do intervals between the different pressure ranges

Hunter quantifying the particle distribution

- Trying to use imageJ
- Haven’t had any luck with using solidworks for this
    - Still looking into this
    - Try posting on a solidworks forum and see if anyone replies?

2021/3/22 - Client Meeting 5

Sara Wagers - Apr 25, 2021, 4:36 PM CDT

Title: 3/22/21 Client Meeting

Date: 3/22/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Skala, Emmanuel

Goals: touch base about goals for the semester and next steps

Content:

- Simulations update
    - Working on the pressures from 0 to 1000 millibar
    - Got the parametric study going
    - Got the pressure and velocity results
        - Still trying to figure out the core diameter thing
            - Emmanuel thinks he knows a way to export the xyz parameters?
                - Want to get the coordinates at the end position to plot the x and y coordinates
    - Snake results
        - Linear up to the point where the cells split into two streams
            - Past 300 millibar for the 50 micron design
                - Between 50 and 100 for the 100 micron design
            - When it splits, the particles are at the same velocity but slower
            - Stay in focus until way high pressure, not seeing a point where the two streams don't have focus
            -
        - See how this relates to figure 4 of the paper?
            - Compare where we are getting the focusing and split paths
    - Funnel results
        - Inlet pressure lower than sheath --- backflow
        - Changing the inner pressure with the same sheath pressure - velocity doesn't change
            - Can he run a parametric with a fixed inner pressure to have less data points?
            - Can fix the inner pressure, and vary the sheath up to 1000
                - Make sure that the cells will still focus
        - Timing out issue
            - Show him a cut plot of the simulation to see what's happening

        - Could be that there isn’t enough inner pressure to get the cells
            - Try to fix the sheath and change the inner pressure to see when the cells can get through

- °

Work on funnel

Try to figure out the focusing on the snake

2021/4/5- Client Meeting 6

Sara Wagers - Apr 25, 2021, 4:34 PM CDT

Title: 4/5/21 Client Meeting

Date: 4/5/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Skala, Emmanuel

Goals: touch base about goals for the semester and next steps

Content:

- Update
    - Outreach this week
        - We've been working on that a lot this week
    - Project updates
        - Cone design
            - Velocity vs pressure
                - With sample set 5 mbar higher than the sheath each time
                - Result is a linear trend
            - Cross sectional plotting
                - Varies by 0.04 mm
                    - Focus confined to this range
                - Try to use a lot more points
                    - Use a filter on the spreadsheet to only get values in the desired range
            - Snake
                - Hunter's results
                    - Trajectory variation in Y
                    - Looks like it's focusing?
    - Fabrication
        - Fabricate some of the bigger channels at the makerspace
        - Printer at morgridge?
            - Might depend on Kayvan's time
            - They will talk and we can try to discuss next week
        - We only have 3.5 weeks
            - Want to validate that the simulations are good
        - To do all of the testing will take months

        - We can try to compare ours with the existing simulations and testing that they already did
    - All good with the sims

2021/4/12 - Client Meeting 7

Sara Wagers - Apr 25, 2021, 4:35 PM CDT

Title: 4/12/21 Client Meeting

Date: 4/12/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Skala, Emmanuel

Goals: touch base about goals for the semester and next steps

Content:

- Josh updates
    - Paper from slack
        - Probability density plots
            - Don’t know if that would work with the data from the simulations
            - It was just an idea to see if that would be something useful
    - Funnel cell spread
        - Standard deviation
            - Gets lower along the length of the channel
    - Could also use this technique for the snake
        - Still takes a lot of work to pull the data needed
            - May not be able to do all of the pressure ranges because of this
    - Data gets 85000 data points
        - Send emmanuel one of the csv files with the 85000 points because he thinks he can sort it
    - Look at a specific slice to be able to see each particle once?
        - Or index the particles somehow so that we know which particle it is in
- Caleb updates
    - Graphs of xz and yx
    - X vz z isn't super helpful?
        - Graph of z vs y
    - Try to show that it is focusing vertically
        - We can see the horizontal focus with the x vs y graph
    - Extend the outlet another centimeter and do a projection of the cells there
        - Look at the cross section another centimeter later -- won't see the bouncing of the cells going through the turns
            - Just rerun one simulation

- To Do:

  Send emmanuel the file to look at

2021/4/26 - Client Meeting 8

Sara Wagers - Apr 27, 2021, 7:54 PM CDT

Title: 4/26/21 Client Meeting

Date: 4/26/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Skala, Emmanuel

Goals: Final meeting to wrap up the project

Content:

Poster comments

- They were small but we could see them
- Want to be able to look at fluorescence decay
    - Cross sectional data
        - Different pressures
        - Will upload to the drive so that they have the raw data to look at
            - They should be able to copy and download stuff from there for their keeping
            - Make sure we give ourselves enough time to make sure that it works
                - Could be difficult -- emmanuel is happy to help troubleshoot
    - What are they looking into in the future

      Data
    - Our project gives them an idea of the ranges they can use with the pump to get the data from their cells

2021/2/5 - Advisor Meeting 1

Sara Wagers - Mar 03, 2021, 12:59 PM CST

Title: Advisor Meeting 1

Date: 2/5/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Williams

Goals: Discuss status of project and goals for the semester

Content:

Semester logistics:

- Outreach
    - We have to find our own group pretty much
        - Talk to Dr. Puccinelli for help with that, see if she knows any opportunities
    - Talk to Dr. Skala about the WID outreach???
        - She can maybe connect us with people through that
    - When we get to doing it, copy him in the email so he knows its done

Presentation

- Video
    - Pre record and he can watch ahead of time, then discuss when we meet
- Focus on the testing and fabrication plans
- Due next friday 2/12

Journal

- Write up as journal article instead of final report
- We need to pick a few journal options for where we would want to publish
    - There are some microfluidics journals out there
        - Lab on a chip
        - Micromachines?
        - Integrative biology

- Design process stuff, like from last semester, would go into an appendix
- George whiteside's How to write a scientific paper
    - Make a rough outline to start and it can help shape how you collect data and stuff
    - Write background and methods and stuff now

Meet with the client

- Catch up with them, see what fabrication stuff was happening
- Ask about access to the fabrication spaces
    - Figure this out early rather than later
- Talk to professor skala and team too
    - Do we just pick one to move forward on?
        - Probably?
        - Snake design more interesting from a design standpoint
            - More parameters to play with
    - Maybe we pursue the snake while they pursue the funnel in parallel
        - Snake fabrication might be easier for us to do
            - Lithography
            - Talk to Beebe lab??

Conclusions/action items:

Next steps:

Talk to skala

Look at journal articles

Come next week with testing plan

2021/2/12 - Advisor Meeting 2

Sara Wagers - Mar 03, 2021, 1:01 PM CST

Title: Advisor Meeting 2

Date: 2/12/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Williams

Goals: Discuss status of project and goals for the semester

Content:

- Video
    - Maybe a little more on the testing plan
    - Almost drawing the graphs out of what you want
        - Make sure we are getting the data that we need to
        - Easier to work backwards
            - Start with the end in mind

- Client meeting
    - Focus on the snake
    - But want us to run a few test with the funnel
    - Fabrication?
        - 3D printer in the WID for the snake design
        - We should think about incorporating connectors into the design
            - Very important
            - Find an stl file for a luer lock????
                - Standard, easy to use, leak free
                - Easy to find the mating connector to hook up to their pumps

- Journal
    - Ones we found are good
    - Look at the author instructions for each
    - Find an article that is something very similar to us… use it as a kinda template to use
    - Start working on the structure and stuff now.

- Access?
    - Last semester no undergrads
    - Talk to them about it in the next meeting with them
        - Testing?
        - Teaching lab sorta accessible but still a process

Conclusions/action items:

Action Items:

- Talk to client about access to the lab
- Look at luer locks
- Talk to TJ Pucc about outreach
- Select a journal type
- Work on designs

2021/2/19 - Advisor Meeting 3

Sara Wagers - Mar 03, 2021, 1:02 PM CST

Title: Advisor Meeting 3

Date: 2/19/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Williams

Goals: Discuss status of project and possible plans for fabrication

Content:

Update:

- Simulations still ongoing or any new info?
    - Heads up in report if we want him to look at anything before a meeting

- Luer locks
    - Pedro resto, former student of williams who did work with luer locks
    - Williams will try to look for something and email it

- Journal choice
    - Biomicrofluidics
    - Find a similar paper to use as a template, include that with progress report
- Fabrication
    - Can we do it at morgridge?
        - Ask them about this on monday when we meet

Conclusions/action items:

Next steps:

Keep working on simulations

Contact middle schools for outreach

Update activity guide

2021/2/26 - Advisor Meeting 4

Sara Wagers - Mar 03, 2021, 1:04 PM CST

Title: Advisor Meeting 4

Date: 2/26/21

Content by: Sara

Present: Josh, Sara, Caleb, Dr. Williams

Goals: Discuss status of project and prelim deliverables

Content:

- Journal
    - Paper looks like a good roadmap
    -
- Deliverables for next week (due next wed)
    - Take materials from last year and cut out stuff that doesn't need to go into the journal article
        - Put all of the design steps and stuff into an appendix
            - Just keep it good and organized
- Project update
    - Client miscommunication
    - Fabrication
        - Kevin Elisieri???
        - The snake still needs to focus better
        - We should try to make plans for how were gonna fabricate
            - Timeline
            - How long after we give them the file will we get the prototype?
    - Slip luer
        - Works well with flexible tubing
            - Barbs on it lock on
        - Found picture of it but not stl file

2021/3/5 - Advisor Meeting 5

Sara Wagers - Apr 25, 2021, 4:16 PM CDT

Title: Advisor Meeting

Date: 3/5/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Williams

Goals: Discuss status of project and prelim deliverables

Content:

- Update on simulations
    - Trying different pressures on the snake design
        - Above 10-15 millibar it's way too fast for it to actually be useable
        - Graph and try to find relationship
    - Planning to crank out a couple more simulations over the weekend
- Luer lock
    - Williams couldn’t find the luer slip stl
    - We will look for a bigger one and see if we can scale down
        - Luer slip is pretty simple
            - Steps that provide more friction
    - When connecting, heat up the silicone a little bit to fit it on and then when it cools its very secure
    - Use an L to keep the tubing out of the way, also reduce vibrations from the pump
        - Route the tubing to the sides
- Particle study
    - Dan Negrut in mech E
    - Does this for his research
    - Should be able to view the cross sectional distribution of where the cells are ending up
        - Take individual slices and export them?
            - Choose a Y-Z cross section
            - Maybe a view or slice function? Not sure
                - Enface - nomenclature for doing this
                - Oblique?
        - Not aware of any automatic way to do it

Action Items:

Try emailing again for outreach

- Finish pressure studies on snake
- Try to find out how to get cross section
- Luer slip stl

2021/3/12 - Advisor Meeting 6

Sara Wagers - Apr 25, 2021, 4:17 PM CDT

Title: Advisor Meeting 6

Date: 3/12/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Williams

Goals: Discuss status of project

Content:

- Where we're at
    - Made spreadsheet with results from simulations
    - Meeting for outreach
    - Working on luer locks
- Interesting results?
    - 1-10 millibar inlet pressure gets the desired velocity at the outlet
        - For all 3 channel sizes?
- Fabrication plans?
    - Working on designing the interface
        - Slip luer in solidworks
- Show and tell
    - No formal show and tell but we can do something optional if we want
    - Fabrication?
        - Other groups maybe have experience with 3D printing microfluidics?
    - Can always throw it out there even if we don't get any help?
- Calendar
    - Williams spring break march 29th-april 2nd
    - 6 weeks until poster presentation

Soft fabrication deadline

Put graphs and results into the report next time

Outreach april 7th at 2:15

Set some more near-term goals

2021/3/26 - Advisor Meeting 7

Sara Wagers - Apr 25, 2021, 4:22 PM CDT

Title: Advisor Meeting 7

Date: 3/26/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Williams

Goals: Discuss status of project

Content:

- Outreach
    - To be completed on April 7th
    - Sent a video to the school to get student interest
- Next friday, 4/2
    - No meeting, university holiday
    - Can talk about other things by email if we need to
- Simulations
    - Still fighting with the long simulation times
    - Data presentation
        - Clients wanted graph from 0 to 1000 mbar for snake design with each channel width
            - Linear to the point where the streams split into two
        - Check with them to make sure that the pressure is constant from the pump
            - Peristaltic would be a constant volume
            - Should be ok if they are able to set what the pressure is from the pump
    - Funnel
        - Trying to graph the data points at the end?
            - Have xyz coordinates as each particle goes down the device
            - 0.04 mm spread, seems reasonable?
                - 40 microns
                - Particles are 10 microns so this seems reasonable
- 4 weeks until poster session
    - Make sure we’re ready to roll for that
    - Fabrication?
        - We can maybe try to give them a pseudo deadline
            - Decide which simulation is going to be the best bet

- Could keep doing simulations forever, but if its easy to fabricate one we should
- The only way to know if the simulation is good is to actually make one and test it…
- In the next week, let’s print one to validate the preliminary conditions
    - We then have time to tweak simulations and make another iteration before the end of the semester

2021/4/9 - Advisor Meeting 8

Sara Wagers - Apr 25, 2021, 4:23 PM CDT

Title: Advisor Meeting 8

Date: 4/9/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Williams

Goals: Discuss status of project

Content:

- Outreach
    - When we submit the stuff cc williams or send him a note to get it checked off
- Executive summary
    - Too long maybe?
    - Probably not enough IP for Tong
- Particle Tracking
    - Hunter’s approach
        - What does the trajectory mean?
            - Where it’s heading or where it is?
                -
        - Is this enough to quantify the spread?
            - Yes
            - Want to get it down to a final number ultimately
            - Spread across is not a normal distribution
                - How do we capture that in a good statistical way?
                    - It's almost bimodal
            - Standard deviation?
                - Could have the same average but standard deviation would tell you which % are falling within the center vs outskirts?
            - Quartile plot
                - How many are in 1st 25%
                - Can give feel for where the majority of the cells are landing

Not recorded

Poster session

Virtual but with a new software

Fabrication

- Clients don’t really want us to
    - They can’t get any of the testing
    - Maybe have them fabricate it so that we can know that they’re fabrication technologies can handle it??
        - Check out the video that they made of the one that they fabricated?
        - Useful to compare it with the simulations we’ve made
        -
- From a class stand point that would’ve been good
    - But it's ok bc of covid

2021/4/16 - Advisor Meeting 9

Sara Wagers - Apr 25, 2021, 4:24 PM CDT

Title: Advisor Meeting 9

Date: 4/16/21

Content by: Sara

Present: Josh, Sara, Caleb, Hunter, Dr. Williams

Goals: Discuss status of project

Content:

- Logistics
  - Outreach is all taken care of
    - Williams is going to verify that we got it uploaded
  - Poster session instructions
    - Email from Pucc
      - Reach out to Williams if we need help with the stats stuff

        He will preview of the poster --- as long as it isn't friday morning

      - Simulations
        - Josh did standard deviation in each direction for funnel
          - Can we characterize the bimodal distribution that is happening?
        - For snake
          - Can we characterize the bimodal distribution that is happening?
          - Width alone or average isn't that helpful
            - Can give false impression that the cells are more in the middle than they are
          - Try to take 2 data sets that look the same and see if the standard deviation is a good representative
          - Quartile plots?
          - Box and whisker plot?
            - How do we present this to differentiate the stream width vs how they are distributed within the width?
          - Nice to put some quantitative analysis on how this is working
            - Shows clear differences between the different designs
              - Nice story to tell
                - We ran into an issue and had to do some extra work to quantify it
                  - T-test isn't good because it doesn't have a normal distribution so we had to do this and this…

2021/3/1 - Outreach Activity Guide

Sara Wagers - Apr 28, 2021, 11:37 AM CDT

Title: Activity Guide

Date: 3/1/21

Content by: Sara

Goals: Activity Guide for use during outreach project

Content:

DEPARTMENT OF
Biomedical Engineering
College of Engineering University of Wisconsin-Madison

Design Inspired by Nature

Organization: University of Wisconsin-Madison Department of Biomedical Engineering

Contact person/s: Sara Wagers, Caleb Heerts, Hunter Hefti, Josh Zembles

Contact information: swagers@wisc.edu, caleb.heerts@wisc.edu, hhefti@wisc.edu, jzembles@wisc.edu

General Description

Small Group Classroom (or virtual) Activity

This activity is designed for middle school students to learn about engineering in a fun and engaging way. This activity has the potential to be conducted virtually should schools be running online in the spring but can also be easily conducted in person. Students will have the opportunity to work in small groups to come up with an invention using the steps of the engineering design process. While doing this they can learn about the interesting things in nature that engineers have been inspired by and they will be challenged to think of creative biomimetic design ideas. If classroom structure permits, they will have fun drawing their designs or creating prototypes out of paper and other supplies.

Idea inspired by activity from eGFI: http://teachers.egfi-k12.org/activity-design-inspired-by-nature/

Program Objectives

Big idea: The overall theme of this outreach activity is to teach students about biomimicry and the engineering design process. It will challenge them to think creatively and seek inspiration from nature.

Learning goals:

As a result of participating in this program, visitors will be able to:

1. Understand how engineering problems can be solved with nature
2. Practice the steps of the design process
3. Define biomimicry and understand how it can be used to inspire creative ideas.
4. Work on a design project with others, practicing crucial teamwork and collaborative skills.

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Time Required

Set-up	Program	Clean Up
(2 minutes)	(35 minutes)	(5 minutes)

Background Information

Definition of terms

Biomedical Engineering: the application of engineering principles and design concepts to medicine and biology for healthcare purposes.

Biomimicry: Copying or imitating the special characteristics of naturally existing things (animals, plants, etc.) in human-made designs, products and systems. From bios, meaning life, and mimesis, meaning to imitate.

Brainstorming: A technique of solving specific problems, stimulating creative thinking and developing new ideas by unrestrained and spontaneous discussion.

Design: To form or conceive in the mind. To make drawings, sketches or plans for a work. To design a new product. To design an improved process.

Engineer: A person who applies scientific and mathematical principles to creative and practical ends such as the design, manufacture and operation of efficient and economical structures, machines, processes and systems.

Inspire: To be the cause or source of; bring about. An invention that inspired many imitations.

Mimic: To imitate or copy.

Engineering design process: The design, build and test loop used by engineers. The steps of the design process include: 1) Define the problem, 2) Come up with ideas (brainstorming), 3) Select the most promising design, 4) Communicate the design, 5) Create and test the design, and 6) Evaluate and revise the design.

Program-specific background

Biomedical Engineering

Biomedical Engineering is the application of engineering principles and design concepts to medicine and biology for healthcare purposes.

Biomimicry

Biomimicry is the emulation of the models, systems, and elements of nature for the purpose of solving complex human problems.

Engineering design process

The design, build and test loop used by engineers. The steps of the design process include: 1) Define the problem, 2) Come up with ideas (brainstorming), 3) Select the most promising design, 4) Communicate the design, 5) Create and test the design, and 6) Evaluate and revise the design.

Materials

- An assortment of:
  - Printer paper
  - Colored pencils/markers/crayons
  - Colored paper
  - Scissors
  - Glue
  - cardboard
  - feathers/glitter/pipecleaners/any other fun craft supplies available
- Materials should be randomly chosen so that students receive a variety of materials to provoke creativity

Set Up

Time: 2 minutes

Step 1:

Arrange tables and chairs to have groups of 3-4 students.

Step 2:

Evenly distribute supplies to each group.

(if virtual, have students/parents gather supplies before the session.)

Program Delivery

Time: 35 minutes

Safety:

Ensure that students can safely use scissors and other materials provided.

Procedure and Discussion:

Step 1: Explain Biomedical Engineering

Does anybody know what biomedical engineering is? Have a volunteer try to define it.

Explain it by breaking it down.

Bio - relating to life

Medical - relating to the science of medicine

Engineering - the branch of science and technology concerned with the design, building, and use of engines, machines, and structures

Step 2: The BME Tracks

Explain each of the 4 engineering tracks.

- Tissue Engineering & Biomaterials
- Bioinstrumentation
- Biomechanics
- Imaging & Optics

Give examples of each of these tracks and how they are valuable to BME.

Step 3: Examples of Real Life BME

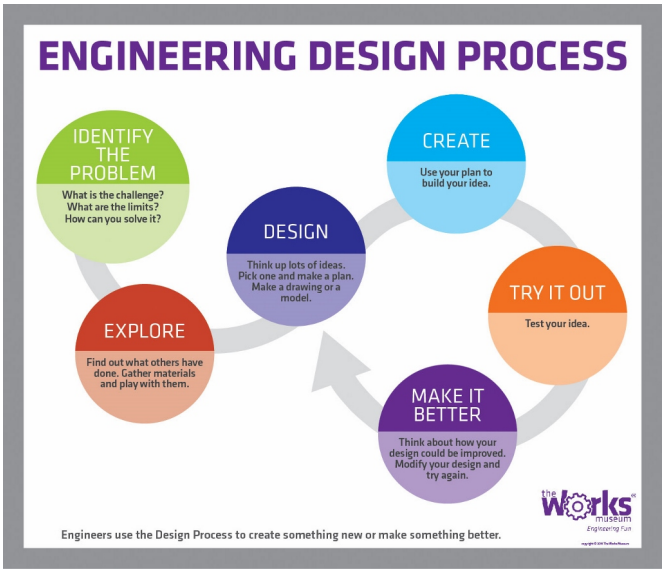
Show the class some examples of our past design projects.

- BME 201 Bioreactor project
- BME 300/301 Organoid Formation

Explain that these projects use multiple BME tracks together. Every track is important to BME.

Step 4: The Engineering Design Process

Talk about what an engineer does. Explain the steps of the engineering design process.

- Identify the problem
- explore/do research
- Brainstorm and Design
- Create
- Test it out
- Make it better
- 

- Today we are going to be engineers and practice the first couple steps of the process

Step 5: Explain Biomimicry

What is biomimicry?

Define it ----- “Biomimicry is when people use ideas from nature to solve problems. Plants and animals have different ways to solve problems that have inspired inventions.”

Step 6: Videos/ Pictures of biomimicry

Show the class a fun youtube video with examples of biomimicry

5 minutes, What is biomimicry and some examples

https://www.youtube.com/watch?v=V2GvQXvjhLA

Step 7: Engineering with Biomimicry

Show and explain examples of engineers using biomimicry. Planes, buildings, etc.

Step 8: Break students up into groups of 3-4 (or 1 if virtual)

Make sure that students are seated in small groups and ready to begin the activity.

Step 9: Explain the Activity

Go through the steps and the basis for the activity.

- Meet your team
- Identify the problem
- Brainstorm
- Design
- Share

Step 10: Meet your team and define the problem.

Tell Students: “Talk to your group and come up with an idea for a problem to solve using biomimicry. This can be something related to a hobby that you both like or something that you want to make better in your life.”

If you can’t come up with an idea, you can use some of these example problems:

- Your gym shoes are too slippery
- You keep ripping the knees on your pants
- You want to jump higher

Give the students 3-5 minutes to discuss before explaining the next step.

Step 11: Become an engineer.

Give students 15-20 minutes to design a new invention that uses biomimicry to solve a problem related to their hobby or one of the suggested problems. The design does not need to be something actually feasible, but students should be as creative with their use of biomimicry as possible.

Students can create a drawing of their designs or use the materials at their table to create a “prototype.”

Step 12: Share ideas.

Each team shares their idea with the class. If time is limited just have each group share with another group around them. (if virtual show the camera what they made)

Step 13: What worked and what didn’t work?

If time permits:

Ask the class what worked well when working as a team?

How did they decide what invention to make?

How did they think like an engineer?

Tips and Troubleshooting:

Encourage students to design an invention related to their shared hobby to help them come up with ideas more easily. Share an example related to one of your hobbies if needed.

Students may need help connecting their designs to biomimicry. Try to give them suggestions and remind them to think about nature.

Going Further…

Provide the students with information about biomimicry websites and where they can go to watch more videos or learn about the research being done.

Clean Up

Time: 5 minutes

Step 1:

Gather markers/crayons/paper/etc. Clean up the work station.

Step 2:

Return tables and chairs to the original classroom setup.

Conclusions/action items:

This guide needs further updating before we complete the outreach, but serves as a good foundation for the project.

2014/4/7 - Outreach Presentation

Sara Wagers - Apr 28, 2021, 11:39 AM CDT

Title: Outreach Presentation

Date: 4/7/21

Content by: Sara, Josh, Hunter, Caleb

Present: Sara, Josh, Hunter, Caleb

Goals: Presentation given to Holmen Middle School for outreach requirements

Content:

See attachment for presentation slides

Sara Wagers - Apr 28, 2021, 11:38 AM CDT

Hefti_Heerts_Wagers_Zembles-outreach-presentation.pdf(3.7 MB) - download Presentation for the outreach activity with Holmen Middle School.

2021/2/15 - 3D Funnel testing with pressure

Josh Zembles - Mar 03, 2021, 1:10 PM CST

Title: 3d Funnel testing with pressure

Date: 2/15

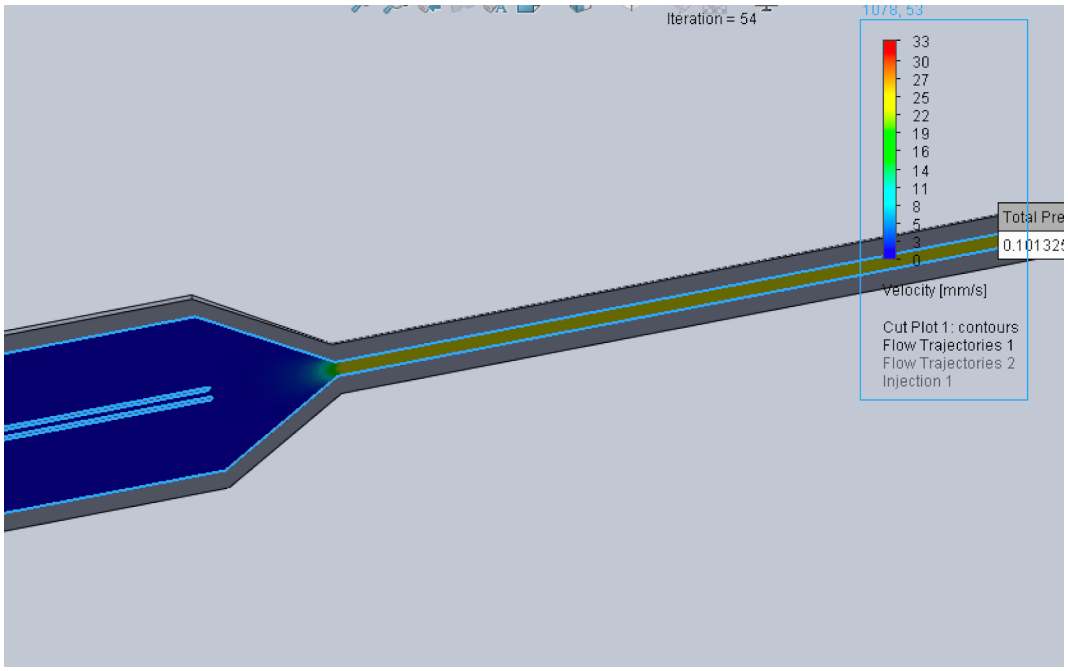
Content by: Josh

Goals: To look at the flow velocity of the fluid with different pressures at the inlets.

Content:

The lowest setting of the pump that would be used in the physical testing is 1 mBar. I started with 1 mBar difference at the inlets compared to the outlet pressure. For both inlets at .101425 MPa and the outlet at .101325 MPa.

With the current physical parameters of the funnel design, the velocity in the channel is about 25 mm/s. This is too fast for the cells to be moving according to the client/product specifications.



Conclusions/action items:

We would need to reduce the inlet sheath diameter to reduce the mass flow rate or increase the diameter of the channel to reduce the velocity by increasing the flow area.

2021/3/3 - 50 um Pressure vs. Velocity Part 1

Josh Zembles - Mar 03, 2021, 1:25 PM CST

Title: Snake 50 um Pressure vs. velocity testing

Date: 3/3/2021

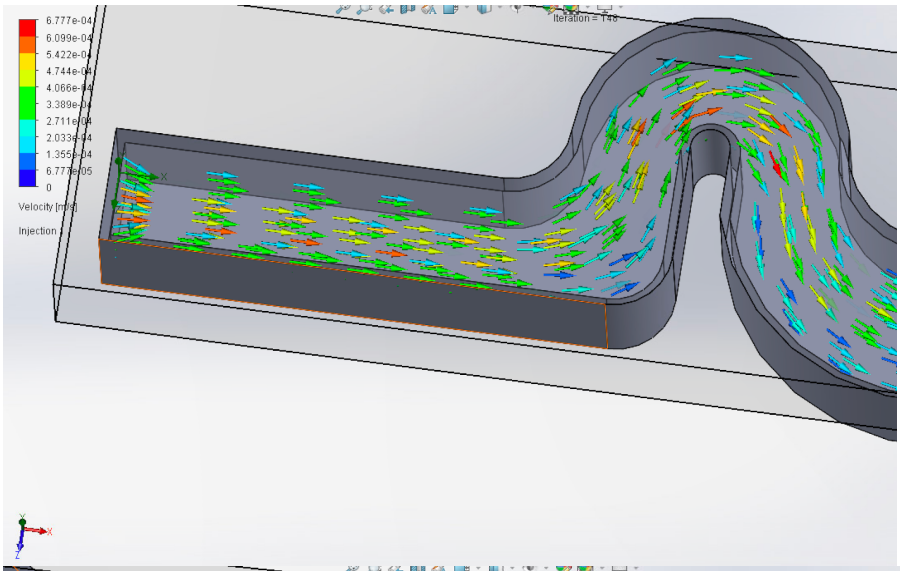
Content by: Josh

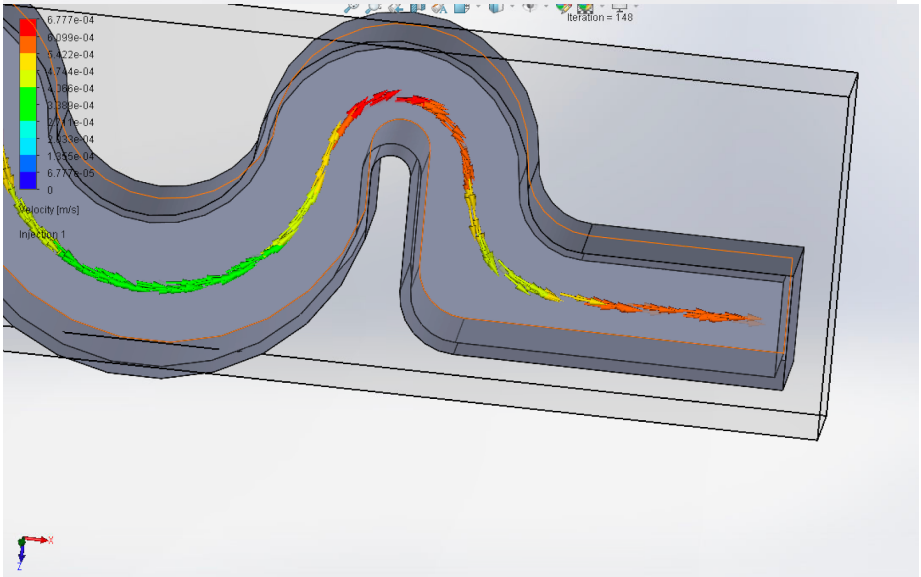
Goals: To test the design at varying pressures and look at focusing and velocity of the cells

Content:

1 mbar pressure

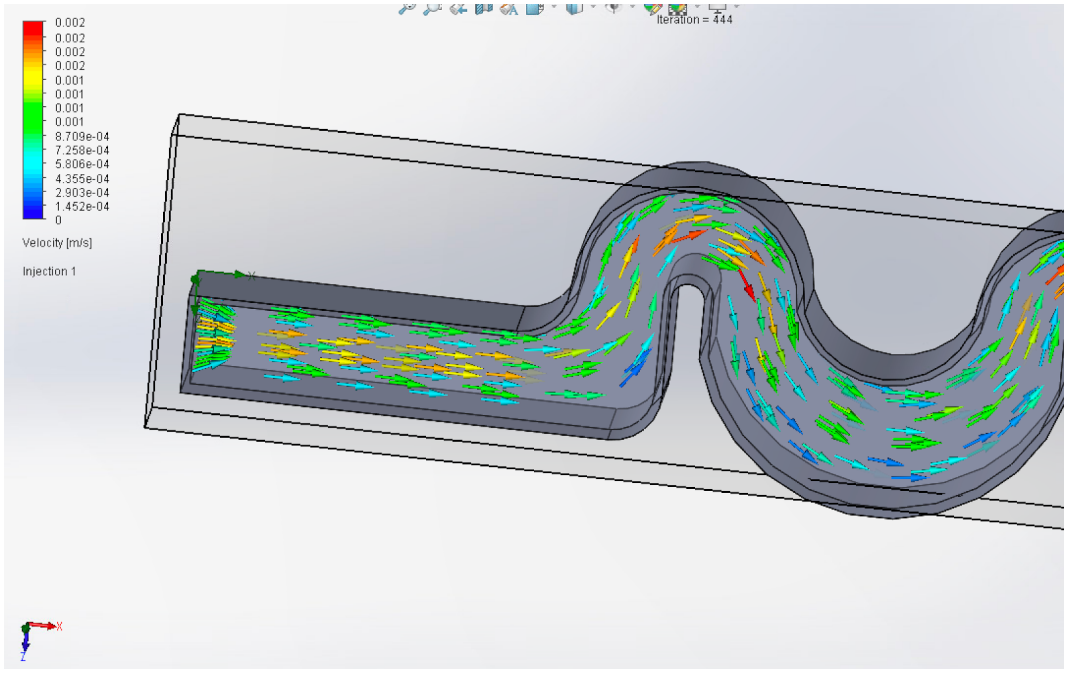
Ending velocity ~ .6 mm/s

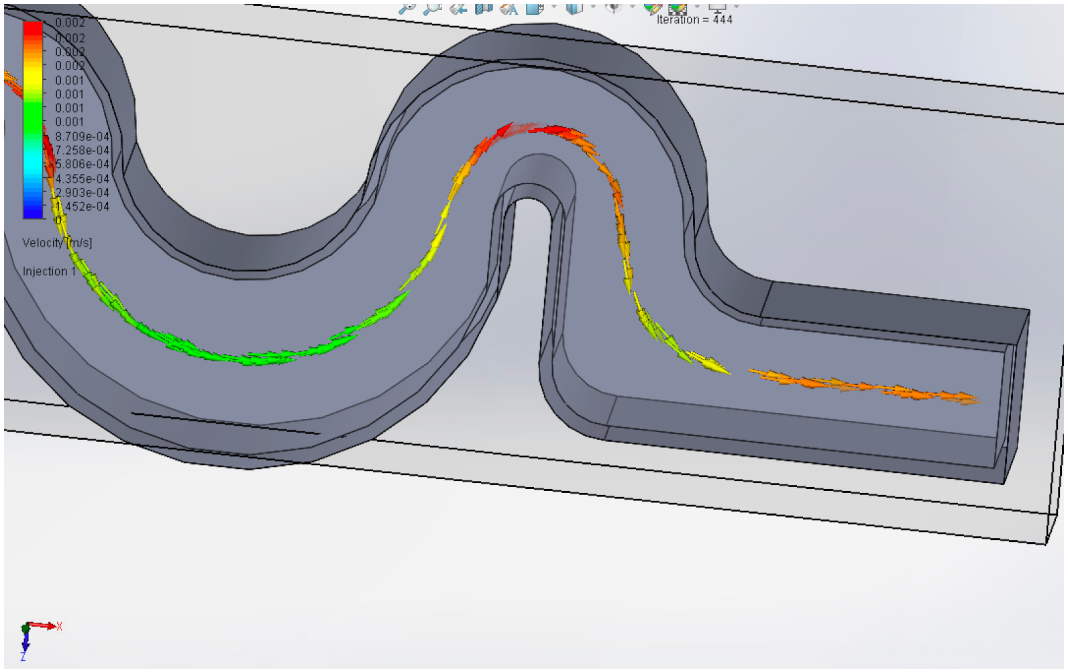




3 mBar

Ending velocity ~ 2 mm/s





Conclusions/action items:

Both pressures tested showed that the cells were focusing in the center by the end of the channel. The ending velocities increased though.

Will be testing more pressures.

2021/3/20 - 50 um Pressure vs. Velocity part 2

Josh Zembles - Apr 28, 2021, 12:46 PM CDT

Title: Snake 50 um Pressure vs. velocity testing

Date: 3/3/2021

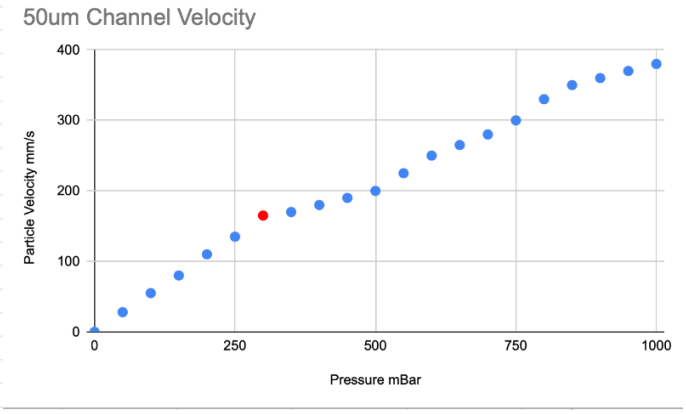
Content by: Josh

Goals: To test the design at varying pressures and look at focusing and velocity of the cells

Content:

We simulated the snake design at 50 mbar intervals to look at the relationship between the pressure and the velocity of the particles. The velocity starts with a linear correlation and then breaks at around 300 mBar. This is due to the fact that the stream of particles are splitting into two separate streams. They are not in the center of the fastest part. of the fluid anymore and are staggered around it.

mBar	Relative Pressure difference	m/s	mm/s	
1013.25	0	0	0	
1063.25	50	0.028	28	
1113.25	100	0.055	55	
1163.25	150	0.08	80	
1213.25	200	0.11	110	
1263.25	250	0.135	135	
1313.25	300	0.165	165	split
1363.25	350	0.17	170	split
1413.25	400	0.18	180	split
1463.25	450	0.19	190	split
1513.25	500	0.2	200	split
1563.25	550	0.225	225	split
1613.25	600	0.25	250	split
1663.25	650	0.265	265	split
1713.25	700	0.28	280	split
1763.25	750	0.3	300	split
1813.25	800	0.33	330	split
1863.25	850	0.35	350	split
1913.25	900	0.36	360	split
1963.25	950	0.37	370	split
2013.25	1000	0.38	380	split



Link to the google sheet with this information: https://docs.google.com/spreadsheets/d/1S_js4OrQFGcX9_WKZaeJe5621ggwf2x_p1aHreGQLDA/edit?usp=sharing

Conclusions/action items:

The relationship between pressures and velocity was characterized for the 50 um snake design.

2021/3/25 - 3D Funnel velocity testing with pressure

Josh Zembles - Apr 28, 2021, 12:58 PM CDT

Title: 3d Funnel testing with pressure

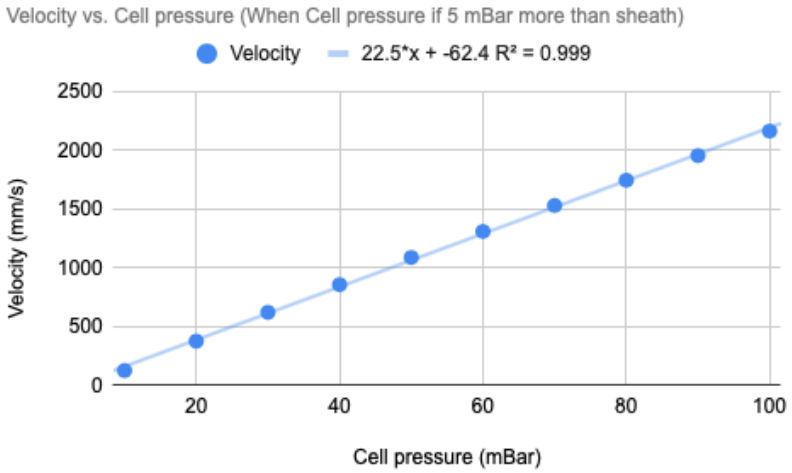
Date: 2/15

Content by: Josh

Goals: To look at the flow velocity of the fluid with different pressures at the inlets.

Content:

Next was to determine the relationship between the pressure input and the velocity of the particles at the end of the Funnel. Since it was previously determined that the velocity does not change when the cell input pressure is changed, the cell input was kept 5 mBar higher than the sheath fluid pressure and then varied the sheath pressure. The cell input was kept 5 mBar higher so that there was no negative gradient of pressure that would cause fluid to exit the input. The particle simulation ran between 1 mBar to 100 mBar in increments of 10 mBar. The results of the particle velocities are shown in Figure 7. The graph shows a linear relationship (R_2 = .999) between the pressure applied and the velocity of the particles.



Link for the data is here: https://docs.google.com/spreadsheets/d/1S_js4OrQFGcX9_WKZaeJe5621ggwf2x_p1aHreGQLDA/edit?usp=sharing

Conclusions/action items:

The relationship between pressures and velocity of particles was established and characterized by the graphed relationship.

2021/4/15 - 50 um Cross Section 1-1000 mBar

Josh Zembles - Apr 28, 2021, 1:00 PM CDT

Title: Snake 50 um Pressure vs. velocity testing

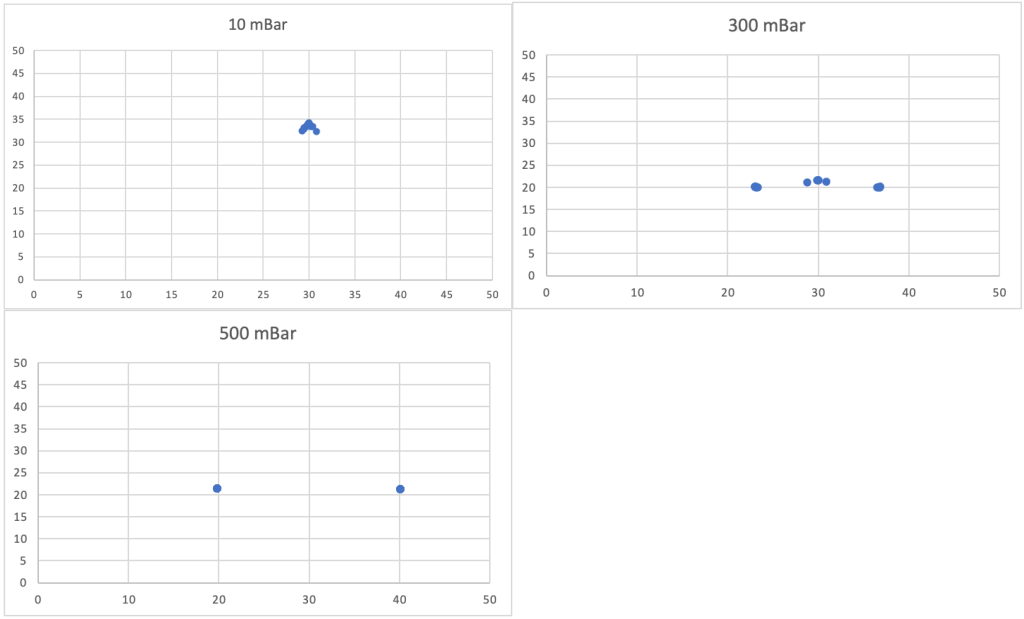
Date: 4/15/2021

Content by: Josh

Goals: To test the design at varying pressures and look at focusing and velocity of the cells

Content:

Attached is the file for particle positional data at the very end of the snake 50 um design. There are graphs of the particles of the Y and Z positions to show the spread of the particles.

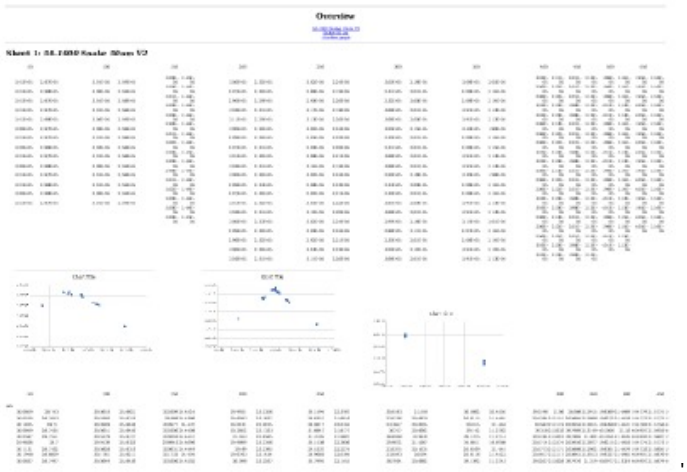


The x axis is the Y coordinate and the y axis is the Z coordinate of the particles. There are all on the same scale (in um).

Conclusions/action items:

The representive graphs above show that at low pressures the particles are confined to one place. But the pressure gets higher, the particles start to split at around 300 mBar and form two separate streams as shown in the 500 mBar pressure.

Josh Zembles - Apr 28, 2021, 12:38 PM CDT



snake50mBarCrossSections.xlsx(84.8 KB) - download

2021/4/20 - 3D Funnel focus testing with pressure

Josh Zembles - Apr 28, 2021, 12:58 PM CDT

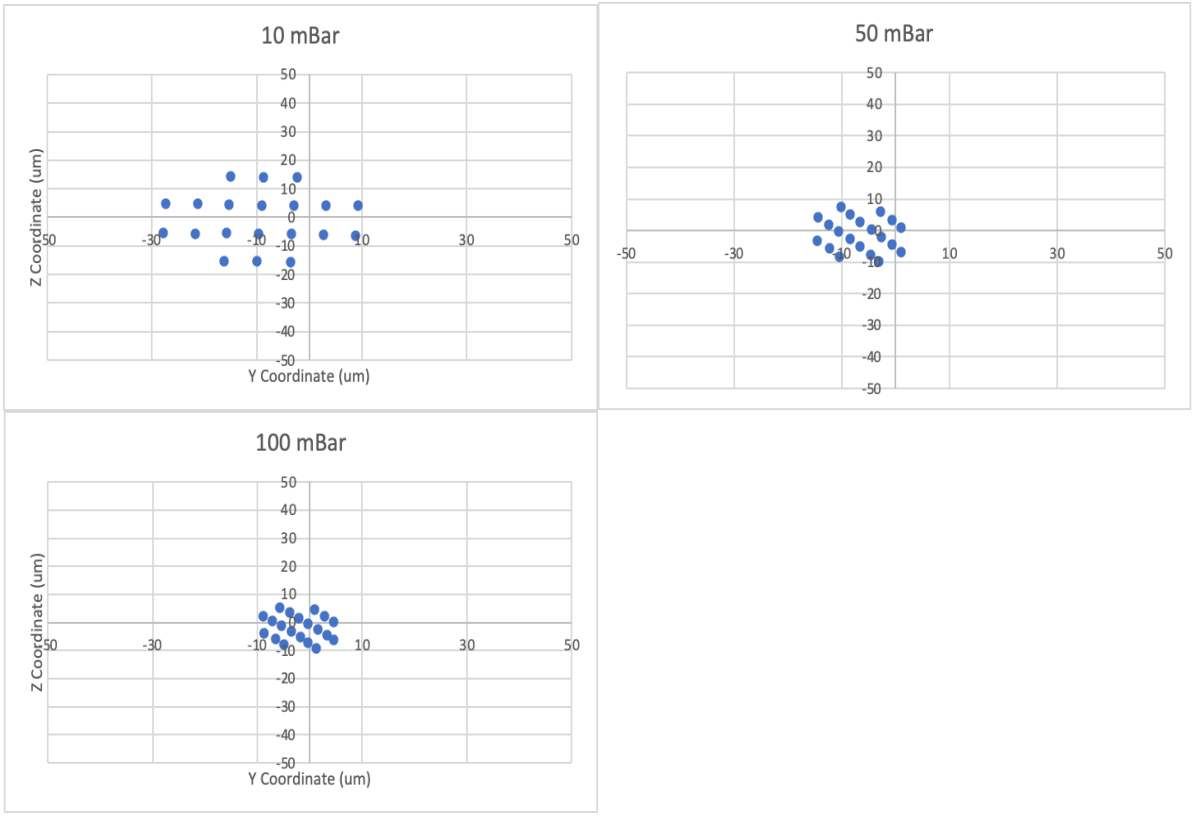
Title: 3d Funnel testing with pressure

Date: 4/20

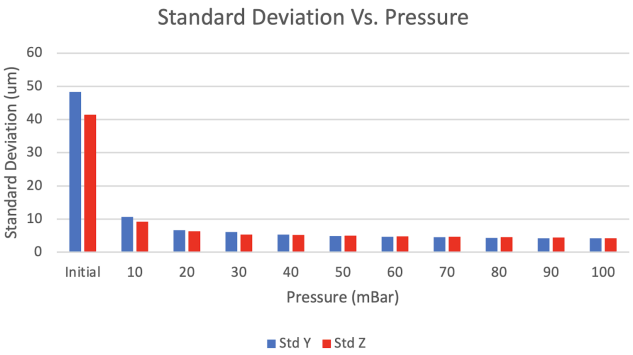
Content by: Josh

Goals: To look at the flow velocity of the fluid with different pressures at the inlets.

Content:



These three plots show that they are focused into a small area within the channel. It also shows that, at higher pressures, the cells become more confined. The spread of the particles was characterized by taking the standard deviation of the Y and Z components of each particle and comparing them to the other pressures. The graph shows that it is able to focus and move the cells closer together. However, the change in the standard deviation plateaus. As the pressure increases, the focusing ability is not significantly affected after 20 or 30 mBar.



Conclusions/action items:

The ability for the funnel to confine the particles was established and characterized by the graphed relationships.

Josh Zembles - Apr 28, 2021, 12:54 PM CDT

3D_Funnel.xlsx(5.1 MB) - download

2021/3/2 Green Pass Permit

Josh Zembles - Mar 03, 2021, 12:57 PM CST

Title: Green Pass Documentation

Date: 3/2/2021

Content by: Josh

Goals: To document the completion of the Green Permit

Content:

Conclusions/action items: I have completed the Green Pass to be able to work in the lab for testing and development of our prototype.

2021/3/2 Biosafety Training

Josh Zembles - Mar 03, 2021, 12:57 P

Title: Biosafety Training Documentation

Date: 3/2/2021

Content by: Josh

Goals: To document the completion of the biosafety training course

Content:

University of Wisconsin-Madison

This certifies that JOSH ZEMBLES has completed training for the following course(s):

Course Name	Curriculum or Quiz Name	Completion Date	Expiration Date
Biosafety Required Training	Biosafety Required Training Quiz	10/22/2018	

Data Effective: Mon Oct 22 15:43:56 2018
Report Generated: Wed Dec 12 01:37:08 2018

Conclusions/action items: I have completed biosafety training to be able to work in the lab for testing and development of our prototype.

2021/3/1 - Luer Locks

Sara Wagers - Mar 03, 2021, 1:26 PM CST

Title: Luer Lock info

Date: 3/1/21

Content by: Sara

Goals: to learn about the use of luer locks in microfluidic connections

Content:

Nie and Takeuchi describe the advantage of using luer locks as connecting valves in 3D printed microfluidics. They explain that the valves can be integrated into the chip for an easy and leak free connection.

https://pubmed.ncbi.nlm.nih.gov/32849974/

This idea was first given to us by Dr. Williams, as a former lab member of his has used luer locks in the past with much success, and this paper further solidifies our motivation for pursuing luer locks as the connection of our device to the pump.

- Further investigation revealed that the former lab member used a slip luer, which we plan to integrate into designs before printing.

Conclusions/action items:

We still need to find or create a solidworks design for the actual valve and add it to the simulations.

2021/3/2 - Journal Article Template Paper

Sara Wagers - Mar 03, 2021, 1:14 PM CST

Title: Journal Article Example Paper

Date: 3/2/21

Content by: Sara

Goals: A roadmap for construction of our journal article

Content:

Serial integration of Dean-structured sample cores with linear inertial focusing for enhanced particle and cell sorting by Holloway et. al.

This paper discusses a similar topic to our inertial (snake design), so we can use it as a model for the formatting and types of information that we should include within our journal article.

Conclusions/action items:

When we are ready to start writing the journal article body, we will use this paper to guide us through the process.

Sara Wagers - Mar 03, 2021, 1:13 PM CST

Holloway_et_al._2018.pdf(1.8 MB) - download

2021/3/12 - Luer Lock Connector

Sara Wagers - Apr 27, 2021, 8:46 PM CDT

Title: Slip Luer Designs

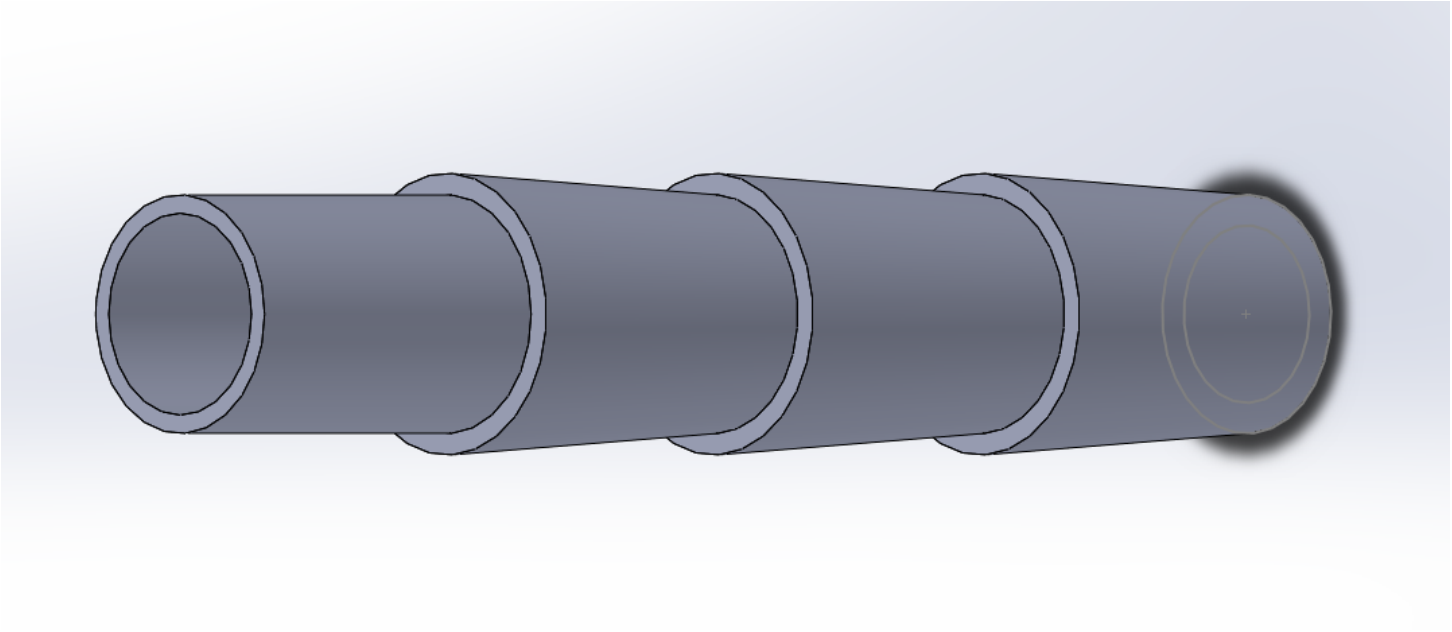
Date: 3/12/21

Content by: Sara

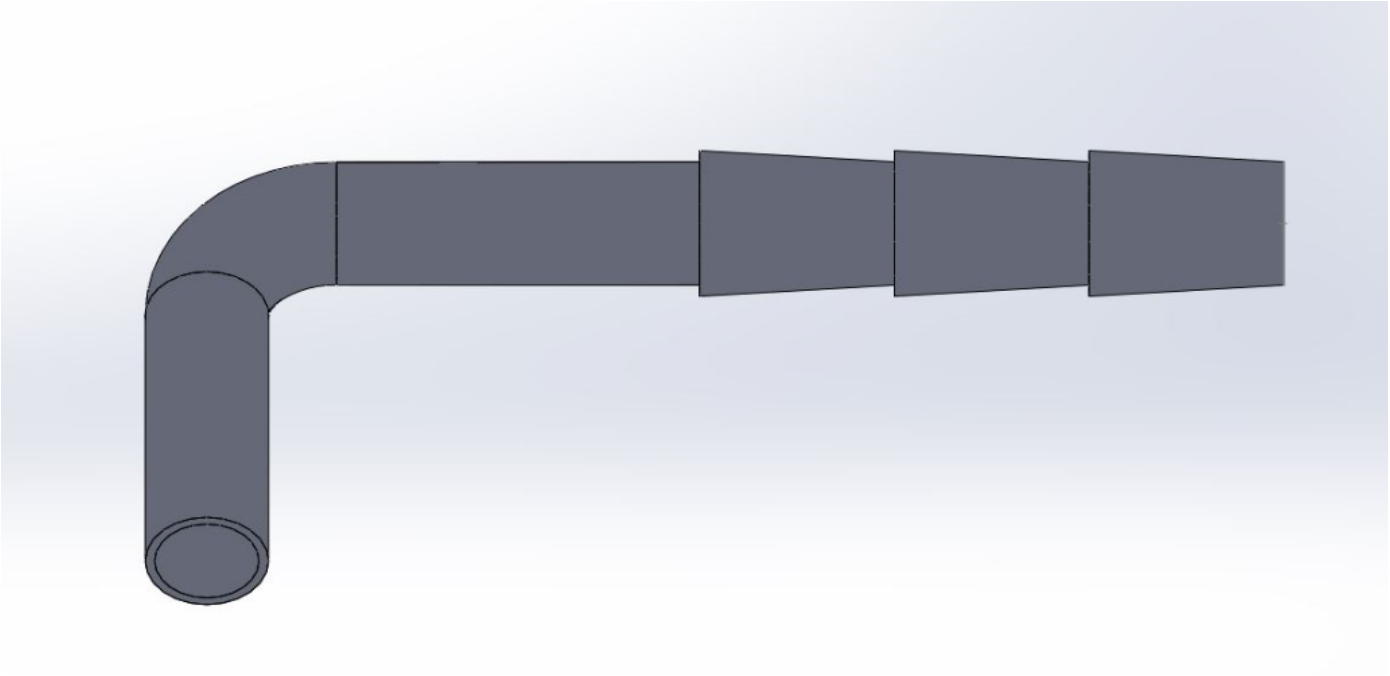
Goals: Modeling of a slip luer connection

Content:

Simple Straight Slip Luer



This design includes three barbs for a tight connection to the tubing. Angle of the tiers was designed based on commercial slip luers and other designs.



The L shaped slip luer was designed to allow for an easier setup. Multiple tubing connections can get messy so the bend allows it to be more out of the way. Dimensions are all the same as the original.

Conclusions/action items:

These should be connected to the designs before printing them to allow connection to the pump.

2021/3/2 Training Documentation

Sara Wagers - Mar 03, 2021, 11:48 AM CST

Title: Training Documentation

Date: 3/2/21

Content by: Sara

Goals: to document the completion of trainings that are required to use the tissue engineering laboratory and lab spaces that may be needed for testing of our prototypes.

Content:

University of Wisconsin-Madison

This certifies that SARA WAGERS has completed training for the following course(s):

Course Name	Curriculum or Quiz Name	Completion Date	Expiration Date
ANIMAL CONTACT RISK QUESTIONNAIRE	ENVIRONMENTAL & OCCUPATIONAL HEALTH	4/17/2020	4/16/2021
ANNUAL HERPES B SAFETY TRAINING	ANNUAL HERPES B SAFETY TRAINING QUIZ	4/19/2019	
ANNUAL HERPES B SAFETY TRAINING	ANNUAL HERPES B SAFETY TRAINING QUIZ 2020	3/30/2020	
BIOSAFETY 102: BLOODBORNE PATHOGENS FOR LABORATORY AND RESEARCH	BLOODBORNE PATHOGENS SAFETY IN RESEARCH QUIZ	4/29/2019	
BIOSAFETY 102: BLOODBORNE PATHOGENS FOR LABORATORY AND RESEARCH	BLOODBORNE PATHOGENS SAFETY IN RESEARCH QUIZ 2020	3/30/2020	
BIOSAFETY 105: BIOSAFETY CABINET USE	BIOSAFETY 105: BIOSAFETY CABINET USE QUIZ	5/20/2019	
BIOSAFETY 106: AUTOCLAVE USE	BIOSAFETY 106: AUTOCLAVE USE: SAFETY AND EFFICACY - VERIFICATION QUIZ	5/20/2019	
BIOSAFETY 107: CENTRIFUGE SAFETY	BIOSAFETY 107: CENTRIFUGE SAFETY VERIFICATION QUIZ	5/21/2019	
BIOSAFETY REQUIRED TRAINING	BIOSAFETY REQUIRED TRAINING QUIZ	10/21/2018	
CHEMICAL SAFETY: FUME HOOD SAFETY TRAINING	FUME HOOD FINAL QUIZ	5/21/2019	
DISPOSING OF HAZARDOUS CHEMICALS	FINAL QUIZ	12/11/2019	
RISK COMMUNICATION IN ANIMAL FACILTIES	RISK COMMUNICATION IN ANIMAL FACILITIES QUIZ	4/16/2019	
SAFETY FOR PERSONNEL WITH ANIMAL CONTACT	ANIMAL CONTACT PERSONNEL QUIZ	4/25/2019	
STEM CELL ETHICS AND POLICY TRAINING	ASSURANCE	5/20/2019	

Data Effective: Wed Jun 17 9:39:03 2020
Report Generated: Wed Sep 23 09:47:47 2020

Conclusions/action items:

I have completed general biosafety training and training necessary to work with cells.

2021/3/2 Green Permit

Sara Wagers - Mar 03, 2021, 11:47 AM CST

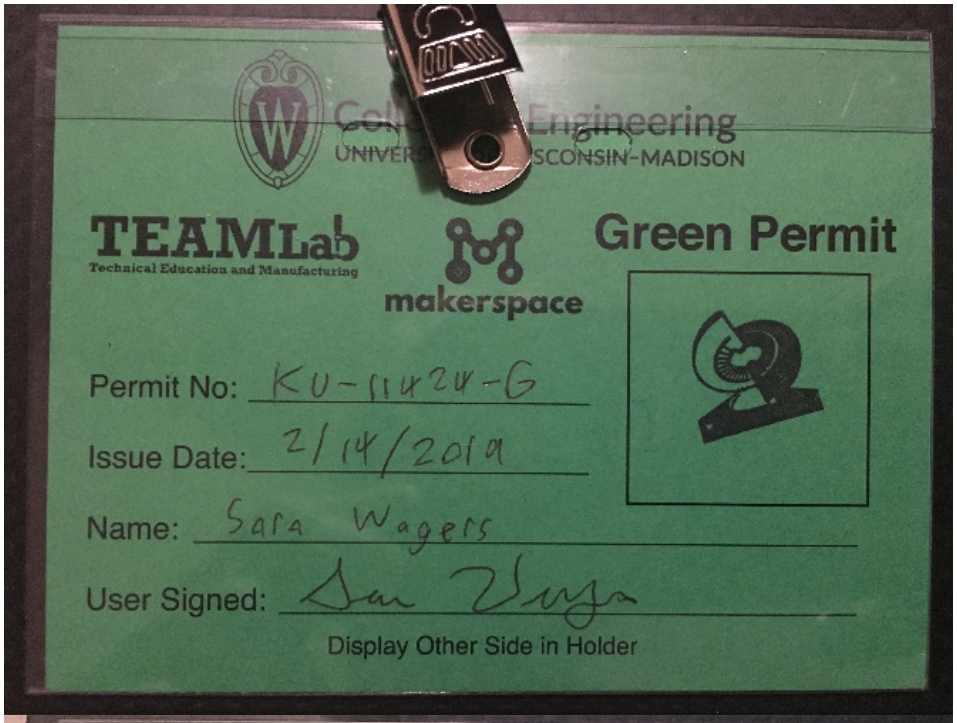
Title: Green Permit Documentation

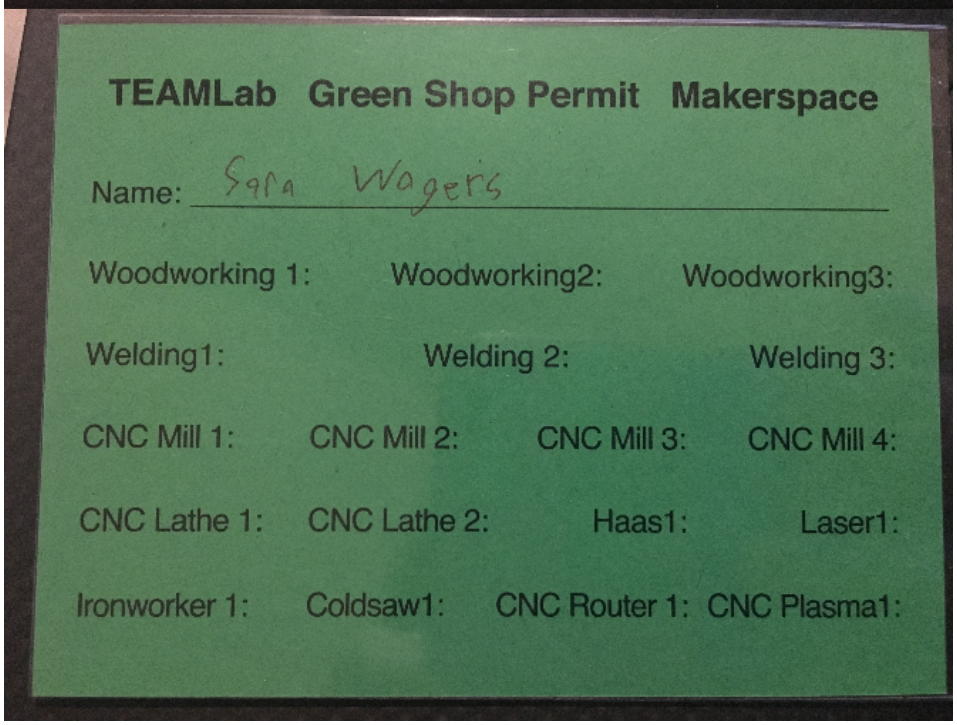
Date: 3/2/21

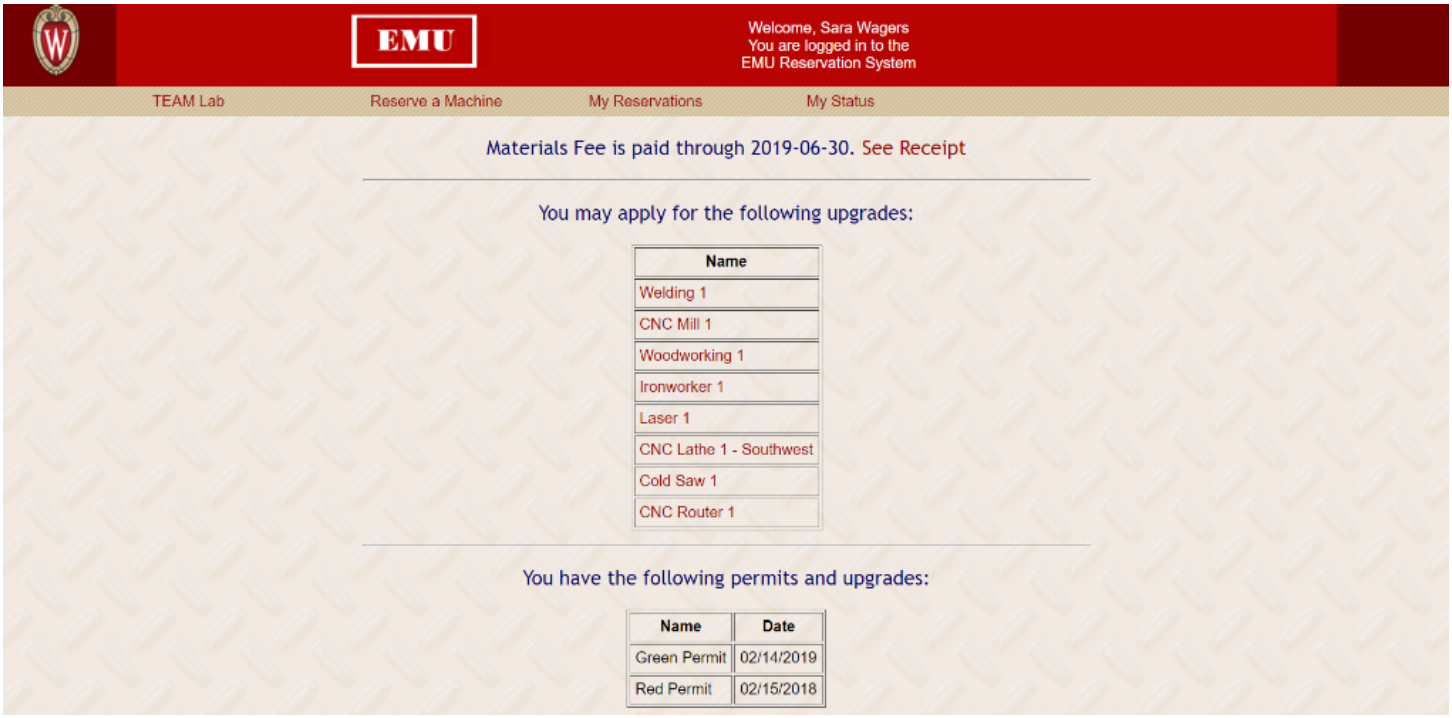
Content by: Sara Wagers

Goals: To document the completion of the green permit

Content:







Conclusions/action items: I have completed the green permit training and will be able to use the tools in the shop to fabricate our device. .

2020/9/12 - Initial presentation

Caleb Heerts - Sep 12, 2020, 12:40 PM CDT

Title: Initial presentation

Date: 9/12/20

Content by: Caleb

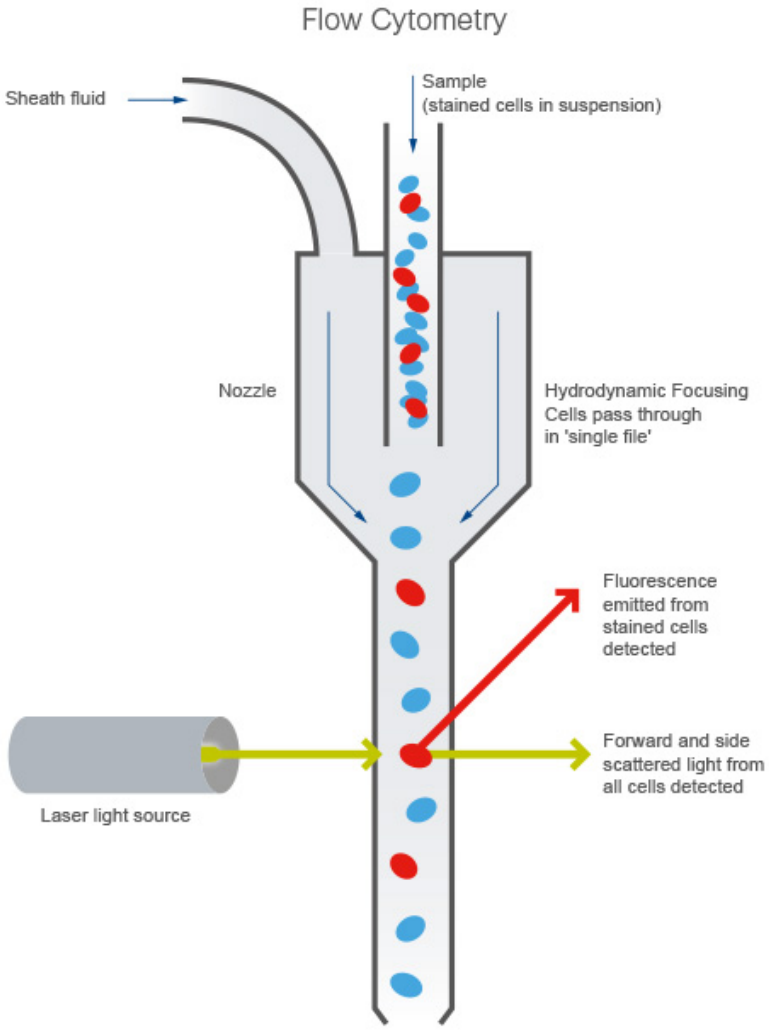
Present: Caleb

Goals: Go over initial presentation info

Content:

https://docs.google.com/presentation/d/18dRaiYMPJV8gdwqXjbExOyJwMrP0juIu/edit#slide=id.p2

- Skala Lab is using Fluorescent Lifetime Imaging (FLIM) to image cellular metabolism on a cell by cell basis and in real time
    - Using light to hit cells and identify the light that passes through/ bounce back
    - Won't need to design this part for the project
- Currently using sheath flow methods for analyzing cells
    - too fast, need the cells to slow down to be analyzed
    - Can't turn down pump as cell flow will stop or become less centralized



    - They've tried a few designs with sheath flow
        - first design had bubbles messing up the flow and it was hard to keep the needle with cells stable
        - Haven't tried the second design
        - need the sheath to be made of either quartz or class so they can image through it
            - not opposed to square or circle sheaths, but need cells to be held fairly in place so they can measure them

- Custom designs from external companies are very expensive -> 4000$ per piece
-

Design Criteria:

Design/Source a flow cell for a flow cytometer given the following constraints:

- Single-file cell flow through interrogation window
- Stable core diameter (20 um to 50 um) (stability in Z more important than X and Y)
- Flow speed of ~1 mm/s, up to 10X faster (at best)
- Flow in PBS (Phosphate-Buffered Saline)
- Bottom side of the flow cell would need to have ~150 micron glass thickness and accommodate the ~1 inch wide objective lens with a working distance of 0.2 mm.
- Entire flow cell would have to fit the microscope stage insert.

CFD simulations for various designs
Explore options for sorting cells at the outlet of the flow cell

"We want single-file cells and stable flow through the center of the interrogation region. Z direction confinement (20 um) and stability is more important than XY plane confinement. That is because the pinhole rejects light from outside of that depth window. We can adjust excitation spot to be oblong in XY but we can't do much about Z"

Here's a website they got a quote about a customer flow cytometer from: https://www.fireflysci.com/custom-quartz-flow-cell-manufacturing

Conclusions/action items:

Look up microfluidic literature and see what kind of work/ designs are out there. Get more familiar with the devices

2020/09/12 - Other designs (from Williams)

Caleb Heerts - Sep 12, 2020, 5:11 PM CDT

Title: Other methods besides sheath flow for the ordering of cells

Date: 9/12/20

Content by: Caleb

Goals: Learn about methods to order cells in microfluidic devices

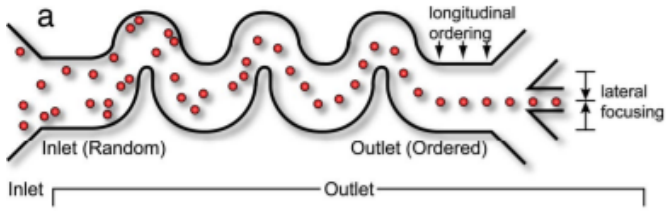
Content:

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5505260/

- Flow cytometers are well-established and researched for collecting data and sorting cells
    - good for analyzing intact cells (versus breaking them apart for analysis)
    - Can usually only analyze cells up to 20 microns in diameter
- Measuring NADH (plays a role as an electron carrier and is involved in metabolic pathways such as glycolysis) is used to study cell metabolism
    - Found bound in mitochondria or free in cytoplasm/ mitochondria
- Flow cytometer testing done with "Hydrodynamic focusing is the process by which two fluids under laminar flow and in common containment remain as separate streams based on differences in density, viscosity, the dimensions of the containment vessel, and/or velocity. This process is commonly used in flow cytometry to alter sample stream dimensions within a flow cell without constructing multiple flow cells of different dimensions."
- Need to watch out for shear forces as a result of flow in microfluidics -> could tear the cells apart

https://www.pnas.org/content/pnas/104/48/18892.full.pdf

- Particles under laminar flow follow fluid streamline
- Particle inertia can be used to align the cells through a differently shapped channel

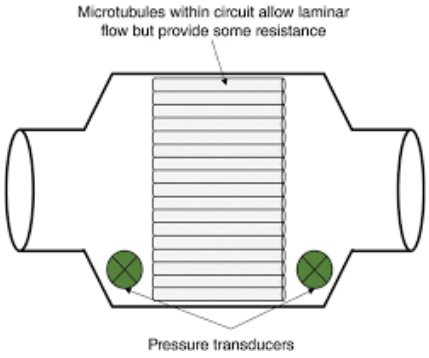


- Faster velocities will create a tighter ordering of the cells (although they will be moving faster)
    - need to watch out for shear forces as the cells speed up as well

Conclusions/action items:

Could we perhaps widen the middle section where the cells are analyzed by splitting it into multiple small compartments (but flow will be reduced overall? Widen the overall area that water is going through, but keep the channel size the same (just allow for multiple channels)

Ex (kind of)


Microtubules within circuit allow laminar flow but provide some resistance
Pressure transducers

2020/09/23 - My design ideas

Caleb Heerts - Se

Title: Other methods besides sheath flow for the ordering of cells

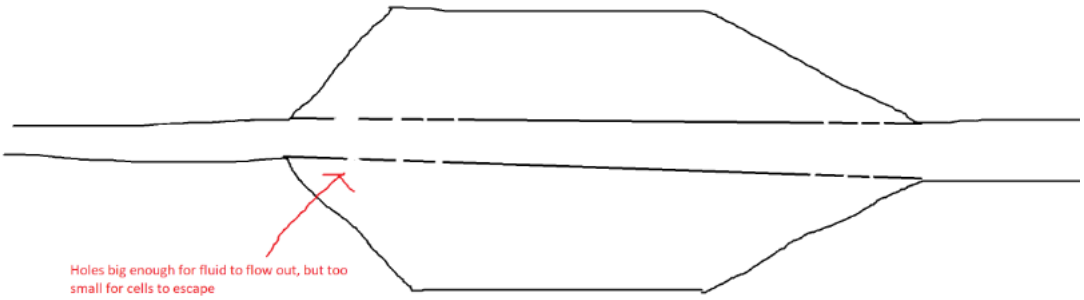
Date: 9/23/20

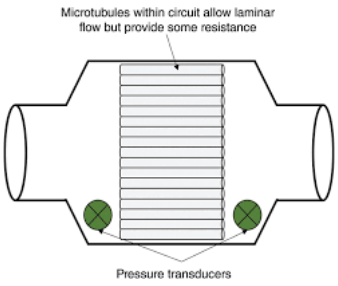
Content by: Caleb

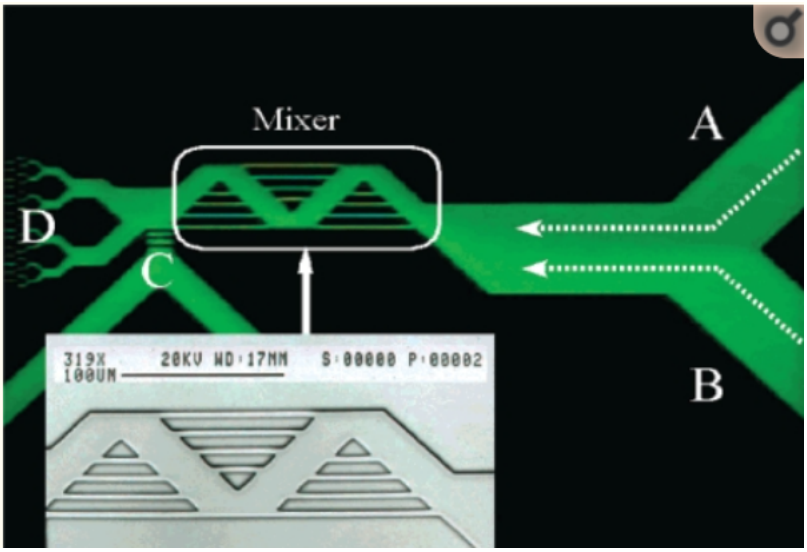
Goals: Brainstorm some ideas for the microfluidic device and constraints

Content:

Design 1:

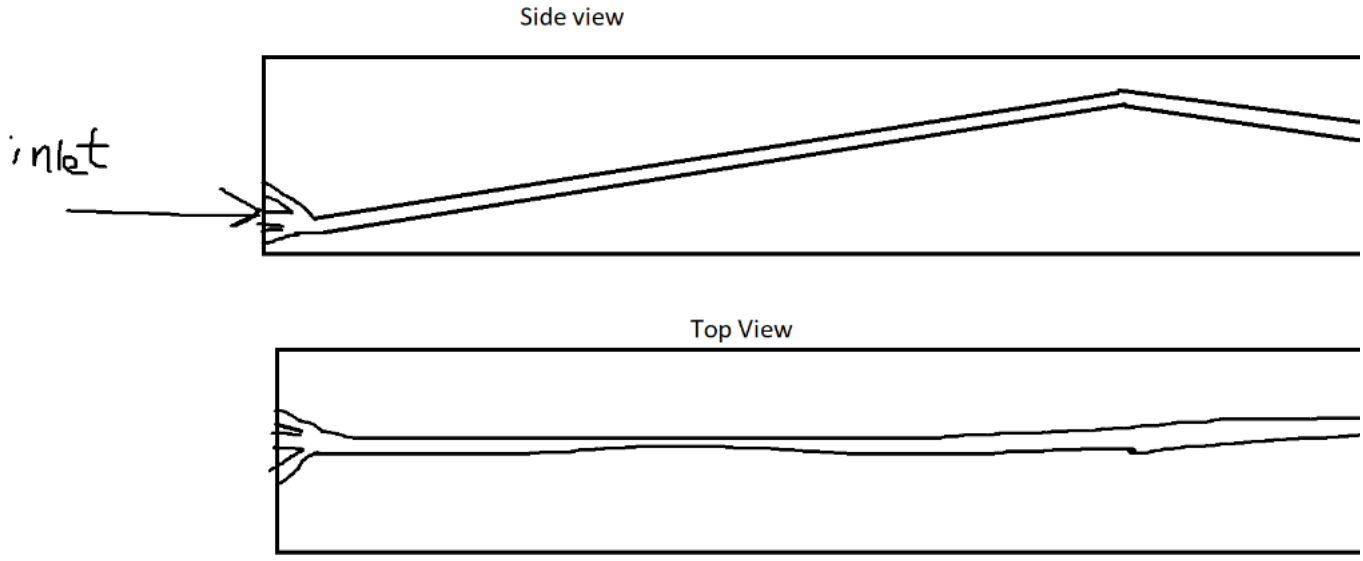


- 

- Similar to this:
- Goal: spread out flow coming in to a greater volume to slow it down, but keep the cells in the same place
- Holes allow for liquid to flow out of main center channel, but cells are stuck in the main center tube for analysis
    - Inner tube could have a fence/ grate like architecture to keep fabrication easier
- See here something similar: 

- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3116190/ (specifically cite 62)

Design 2



-
- Use of gravitational forces to slow down fluid as it climbs uphill
  - worry about slowing down too much (lose laminar flow/ potential of backflow?)
- Have to remove some of the excess material off the bottom to give a consistent Geometry for the laser to pass through
  - can we have an angle?
  - Do we have to have the main catheter line exposed for the laser?

Conclusions/action items:

2020/10/04 Microfluidic companies

Caleb Heerts - Oct 16, 2020, 1:26 PM CDT

Title: Microfluidic companies

Date: 10/4/2020

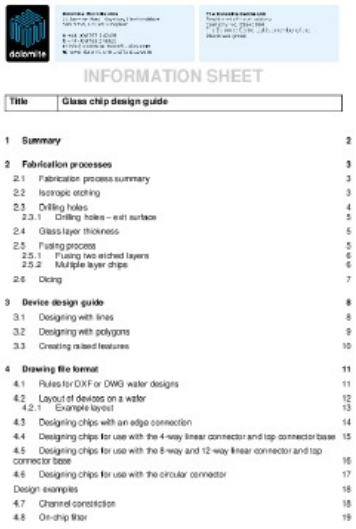
Content by: Caleb

Content:

Elveflow Microfluidics	Our core expertise is premium flow control equipment, we have a broad range of pumps, valves, sensors used for many various applications.	referred us to Darwin Microfluidics
Darwin Microfluidics	offer a wide range of chip solutions in various materials (polycarbonate, COC, COP, etc.).	PMMA may work as a material
Dolomite Microfluidics	we fabricate glass or quartz chip using an isotropic wet etching process. We do not work with PDMS. Custom glass devices are made in wafers of glass that are 100mm x 100mm square in size. These are then processed and fused together to create a complete wafer, but then cut into pieces to make your chips. The cost of the first prototype wafer can vary between $5,000 to $20,000 depending on the design and the processes needed. These costs include the costs of tooling that needs to be made only one time. The cost of making more of exactly the same wafers after this then falls very much. The only materials that we fabricate chips from are glass and quartz.	if you are looking at only one chip, the cost would be quite high. If you need several chips, then it becomes more cost efficient. Note also that we cannot do rectangular or square channels as we use wet-etching with HF technique to create channels in the glass.

Conclusions/action items:

Caleb Heerts - Oct 05, 2020, 3:52 PM CDT

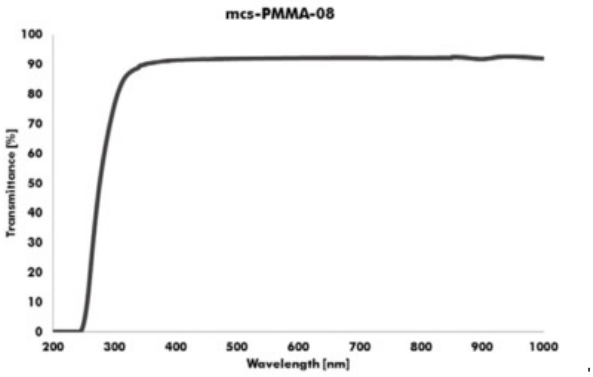


INFORMATION SHEET

Title	Glass chip design guide

Dolomite_Microfluidics_Manufacturing.pdf(913.7 KB) - download

Caleb Heerts - Oct 07, 2020, 12:11 PM CDT



transmittance_of_pmma.png(77 KB) - download

2020/10/5 Microfluidic sorting (Inertial Sorting)

Caleb Heerts - Oct 12, 2020, 4:52 PM CDT

Title: Microfluidic Sorting techniques

Date: see above

Content by: Caleb H

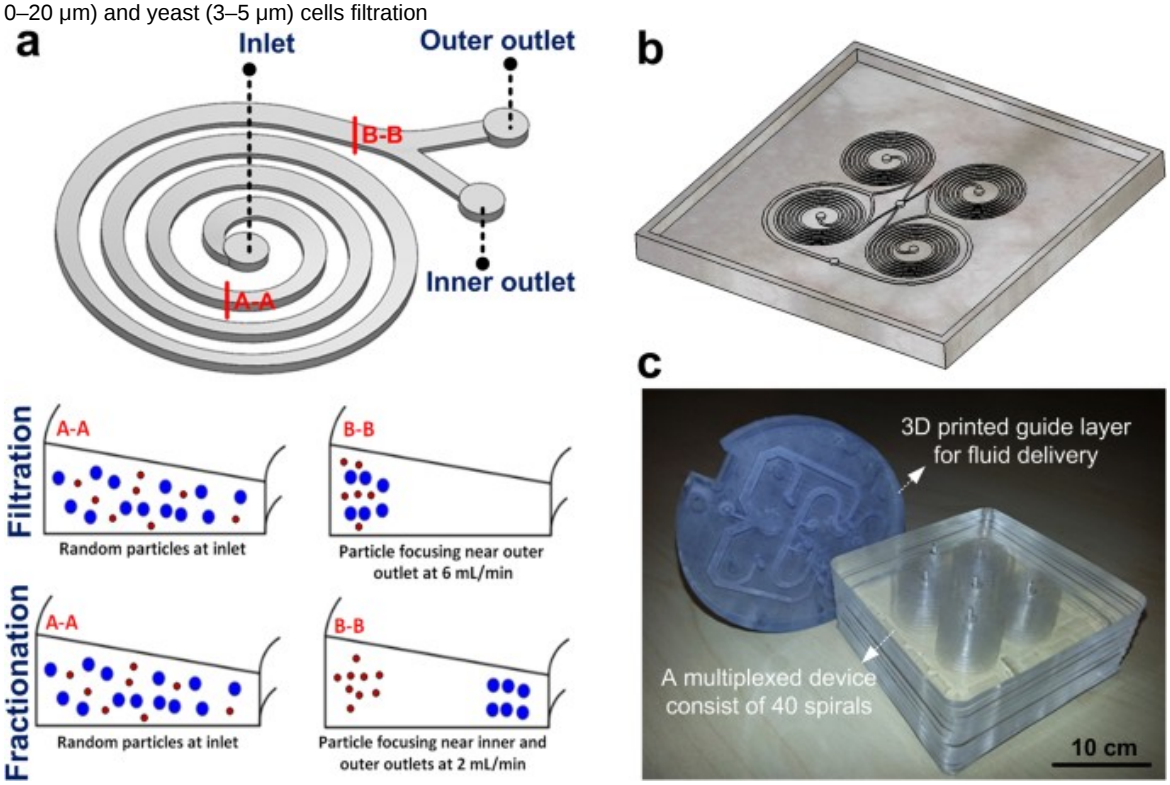
Goals:

Content:

https://www.elveflow.com/microfluidic-reviews/microfluidics-for-cell-biology/label-free-microfluidic-cell-separation-and-sorting-techniques-a-review/ (many options here)

https://www.nature.com/articles/srep11018 (inertial size sorting)

- 500mL/min for the stacked channels
- 0–20 μm) and yeast (3–5 μm) cells filtration



- Spiral filtration method
- Used PDMS as a material
- The spiral device used in this study for mammalian cell retention and fractionation was an 8-loop spiral microchannel with one inlet and two outlets with radius increasing from 8 mm to 24 mm for efficient cell migration and focusing

https://www.pnas.org/content/pnas/104/48/18892.full.pdf

- Square channels used
- 9-micro m-diameter particles in a square channel (50 micro m)
- . The equilibrium position for particles is ~9 micron from the channel edge

https://www.biorxiv.org/content/10.1101/862227v2.full

- Used soft lithography with PDMS and a mylar mask
-

Conclusions/action items:

11/5/20 - Snake Design - SolidWorks

Title: Snake Design Solidworks and Analysis pictures

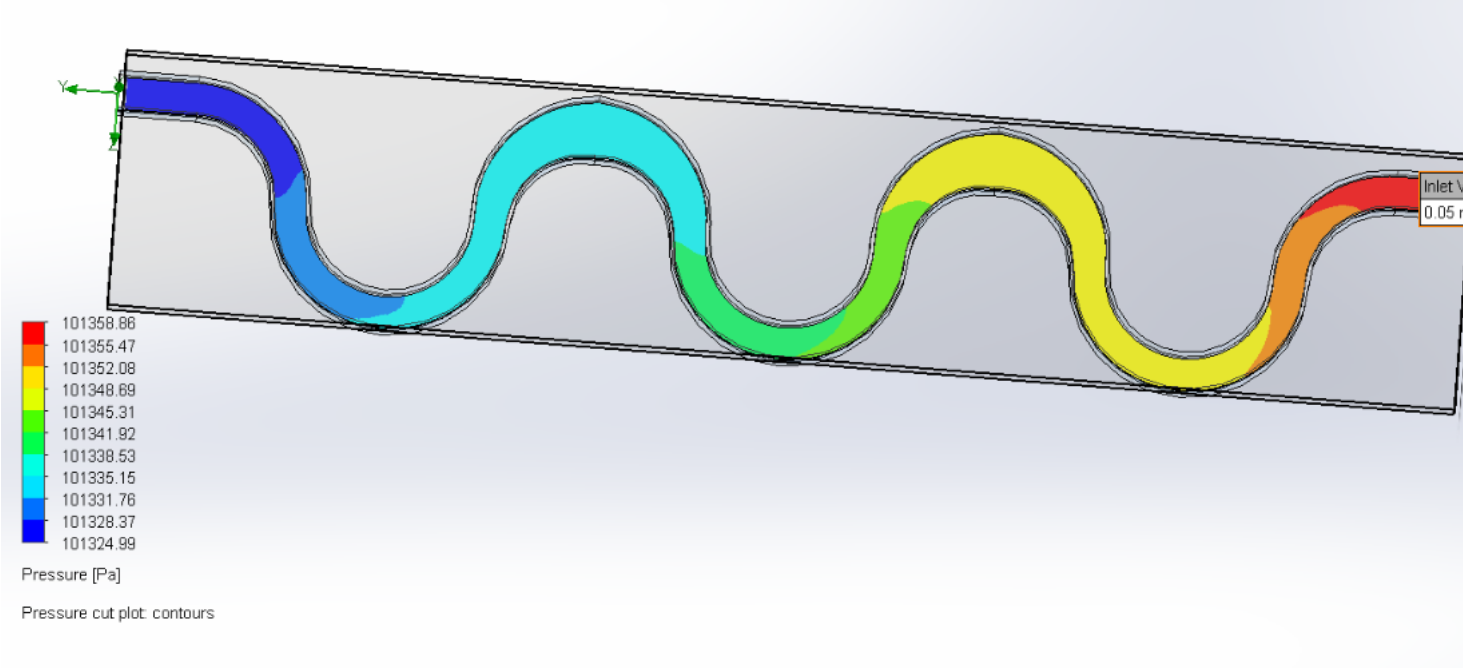
Date: 11/5

Content by: Caleb

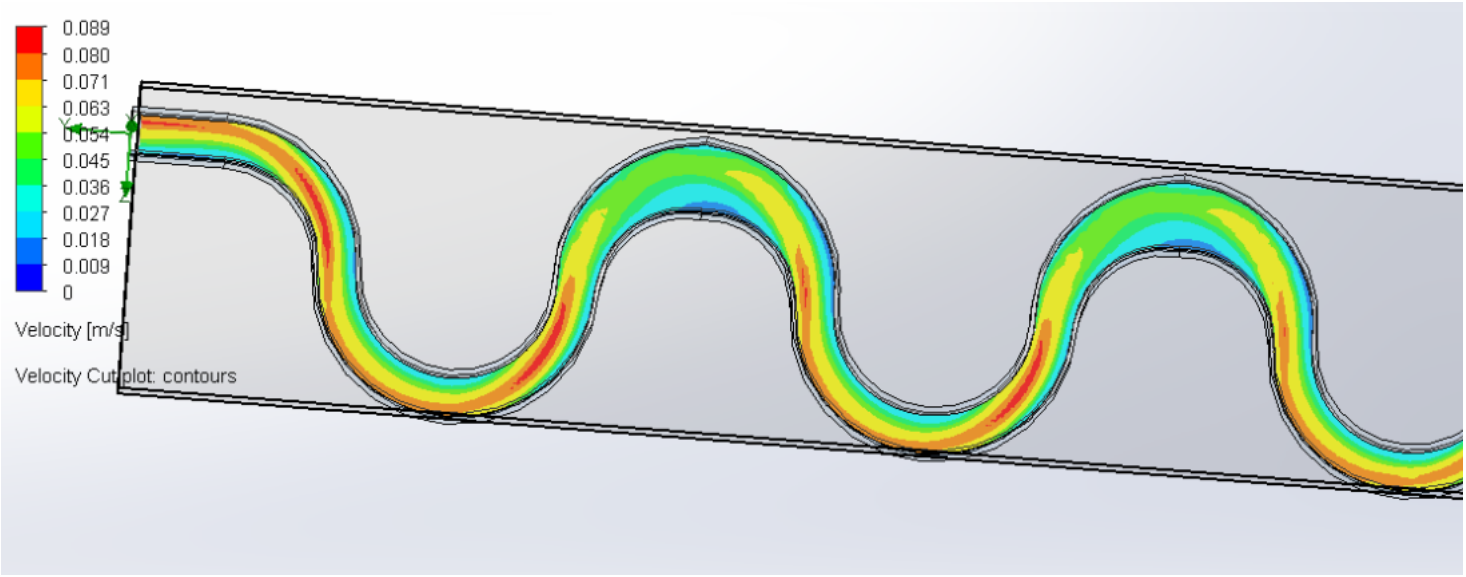
Goals: Look at the snake design and analyze the fluid flow

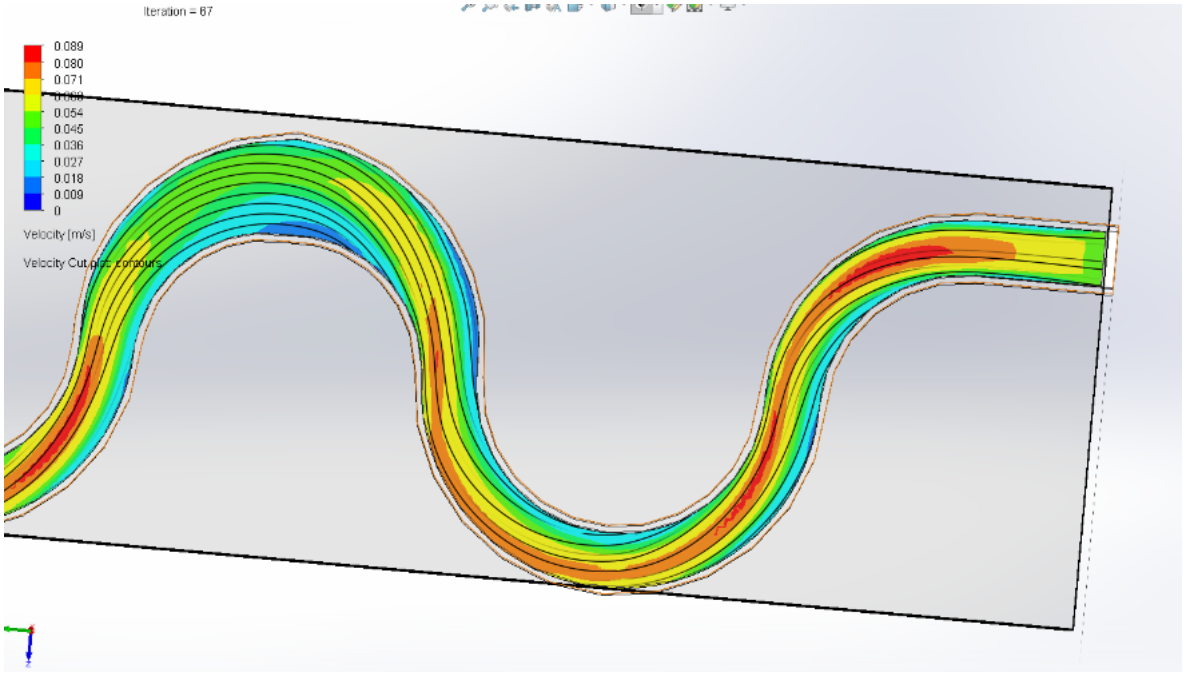
Content:

Pressure Cut Plot:



Velocity Cut Plot:

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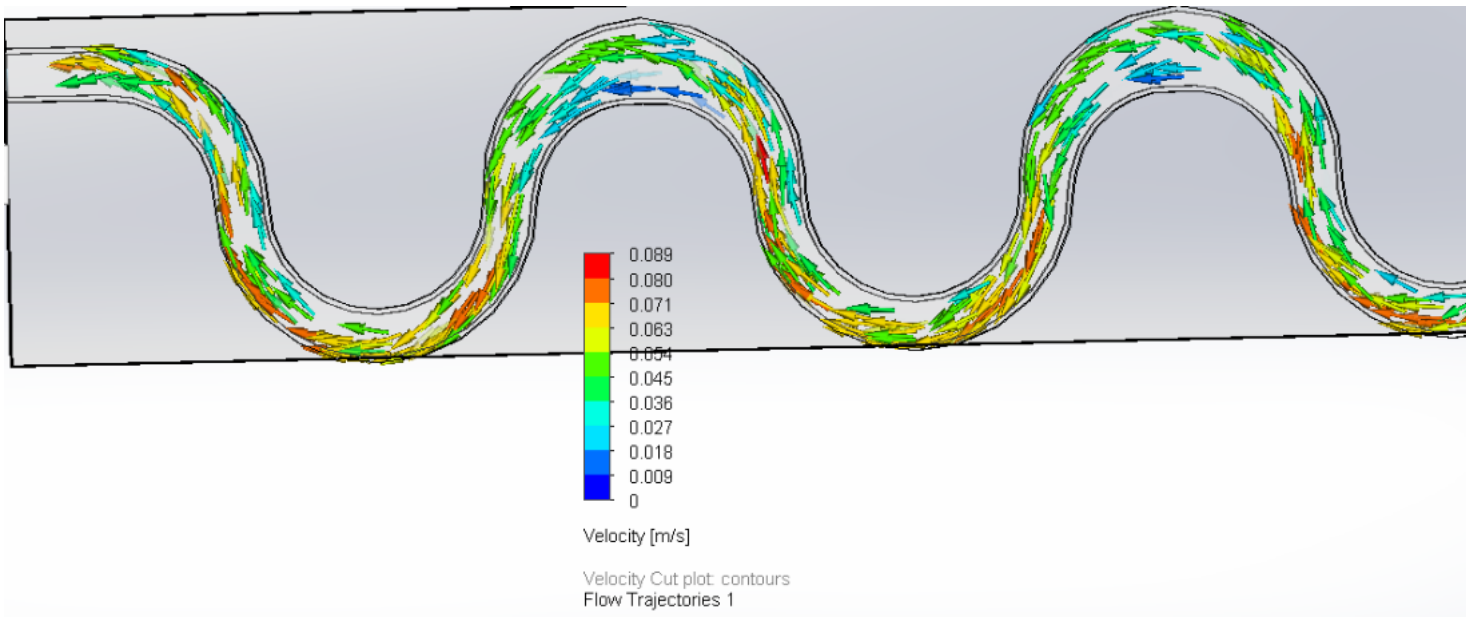
Velocity [m/s]
Velocity Cut plot: contours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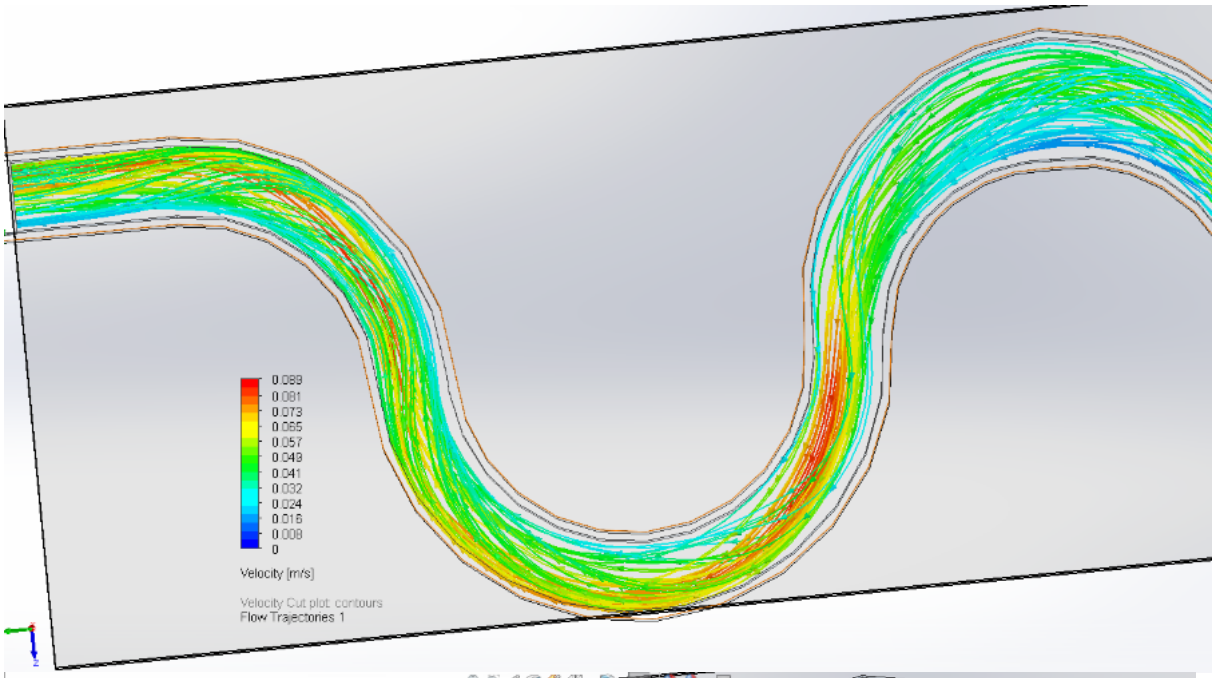
0.018
0.009
0
Velocity [m/s]
Velocity Cut plot: contours
Flow Trajectories 1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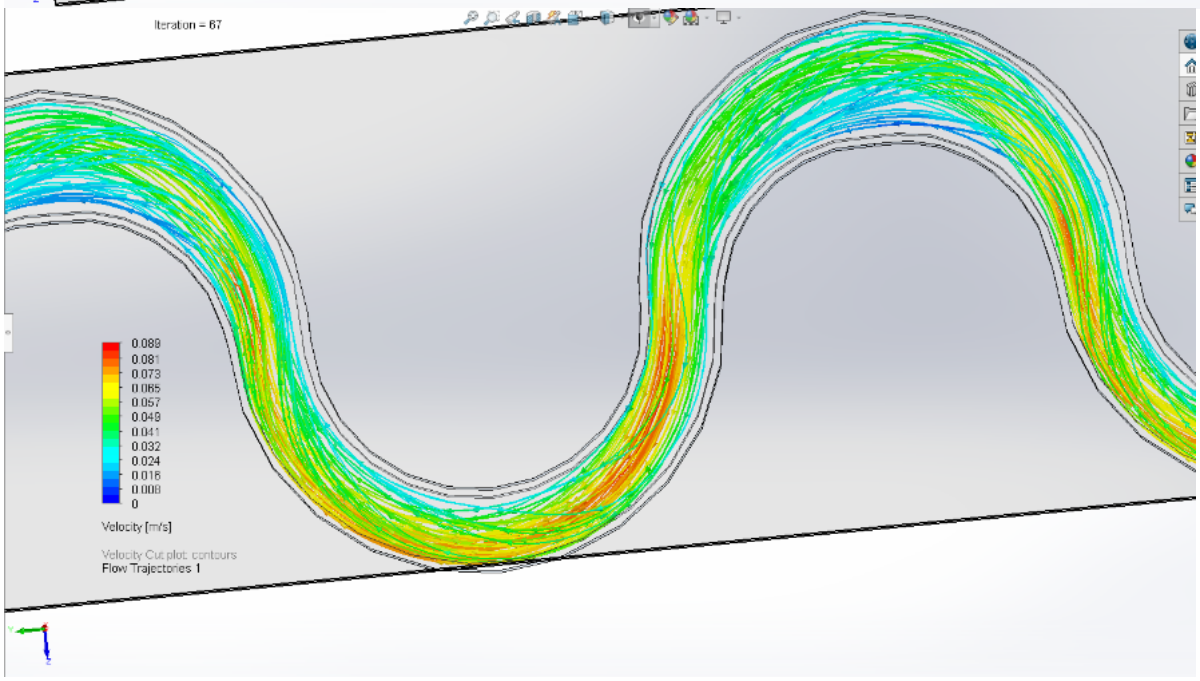
Velocity [m/s]
Velocity Cut plot: contours
Flow Trajectories 1


Iteration = 67
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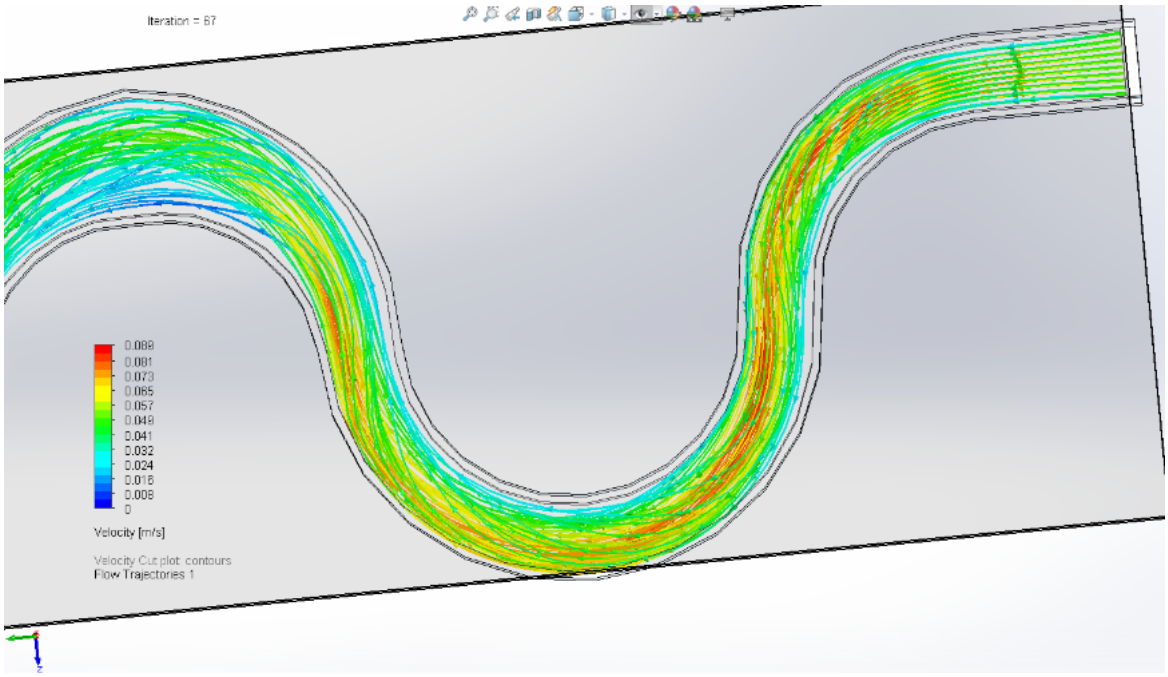
Velocity [m/s]
Velocity Cut plot: contours
Flow Trajectories 1



Conclusions/action items:

Caleb Heerts - Nov 05, 2020, 8:46 PM CST

Snake.sldprt(198.3 KB) - download

Caleb Heerts - Nov 05, 2020, 8:46 PM CST

Snake_project_folders.html(543 Bytes) - download

12/5/20 - Snake Designs - SolidWorks

Caleb Heerts - Dec 09, 2020, 12:40 PM CST

Title: Snake Design Solidworks and Analysis pictures

Date: 11/5

Content by: Caleb

Goals: included are the other snake designs

Content:

Conclusions/action items:

Caleb Heerts - Dec 09, 2020, 12:40 PM CST

Snake_2.SLDPRT(96.5 KB) - download

Caleb Heerts - Dec 09, 2020, 12:40 PM CST

Snake_4.SLDPRT(168.6 KB) - download

Caleb Heerts - Dec 09, 2020, 12:40 PM CST

Snake.sldprt(167.4 KB) - download

Caleb Heerts - Dec 09, 2020, 12:40 PM CST

Snake_project_folders.html(543 Bytes) - download

Caleb Heerts - Dec 09, 2020, 12:40 PM CST

Snake3.SLDPRT(260.6 KB) - download

Caleb Heerts - Dec 09, 2020, 12:40 PM CST

Snake3_project_folders.html(538 Bytes) - download

2/20/21 - Other snake design (failures)

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

125umSnake.SLDPRT(293.8 KB) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

125umSnake_project_folders.html(548 Bytes) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

100umSnake.SLDPRT(325.9 KB) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

100umSnake_project_folders.html(546 Bytes) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

Snake3.SLDPRT(260.6 KB) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

Snake3_project_folders.html(538 Bytes) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

Snake.sldprt(167.4 KB) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

Snake_project_folders.html(543 Bytes) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

Snake_2.SLDPRT(96.5 KB) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

Snake_4.SLDPRT(168.6 KB) - download

Caleb Heerts - Mar 01, 2021, 9:09 PM CST

Snake_2021_50micron.SLDPRT(100.3 KB) - download

3/1/21 - Working Snake Designs

Caleb Heerts - Mar 01, 2021, 9:10 PM CST

150umSnake2.SLDPRT(1.6 MB) - download

Caleb Heerts - Mar 01, 2021, 9:10 PM CST

150umSnake2_project_folders.html(672 Bytes) - download

Caleb Heerts - Mar 01, 2021, 9:10 PM CST

100umSnake2.SLDPRT(1.6 MB) - download

Caleb Heerts - Mar 01, 2021, 9:10 PM CST

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100umSnake2_project_folders.html(674 Bytes) - download

Caleb Heerts - Mar 01, 2021, 9:10 PM CST

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50umSnake2.SLDPRT(1.2 MB) - download

Caleb Heerts - Mar 01, 2021, 9:10 PM CST

,

50umSnake2_project_folders.html(672 Bytes) - download

4/25/21 Long Snake cell centering

Caleb Heerts - Apr 25, 2021, 4:03 PM CDT

Title: Long snake (w/ 10mm straight extension) cell centering

Date: 4/25

Content by: Caleb Heerts

Content:

Caleb Heerts - Apr 25, 2021, 4:09 PM CDT

Particle_Study_Long_boy_Injection_1.xlsx(123.8 MB) - download

Caleb Heerts - Apr 25, 2021, 4:12 PM CDT

Particle_Study_1_Injection_1.xlsx(121.5 MB) - download

4/25/21 Exported particle study data

Caleb Heerts - Apr 25, 2021, 4:14 PM CDT

Title: exported xlsx particle study data

Date: 4/25

Content by: Caleb Heerts

Content:

Caleb Heerts - Apr 25, 2021, 4:28 PM CDT

150um_snake-20210425T210422Z-001.zip(736.3 MB S3) - download

2020/10/04 Biosafety Training

Caleb H

Title: Biosafety Training Documentation

Date: 10/4/2020

Content by: Caleb H

Goals: To verify the completion of the biosafety training course

Content:

University of Wisconsin-Madison

This certifies that CALEB HEERTS has completed training for the following course(s):

Course Name	Curriculum or Quiz Name	Completion Date	Expir
Biosafety Required Training	Biosafety Required Training Quiz	3/16/2019	
Chemical Safety : Hazard Communication with Globally Harmonized System (GHS)	Hazard Communication with GHS Update Quiz	9/10/2017	

Data Effective: Sat Mar 16 15:58:39 2019
Report Generated: Wed Oct 9 01:39:35 2019

Conclusions/action items: I have completed biosafety training to be able to work in the lab for testing and development of our prototype.

2020/10/04 Green Pass Permit

Caleb Heerts - Oct 04, 2020, 9:23 PM CDT

Title: Green Pass Documentation

Date: 10/4/2020

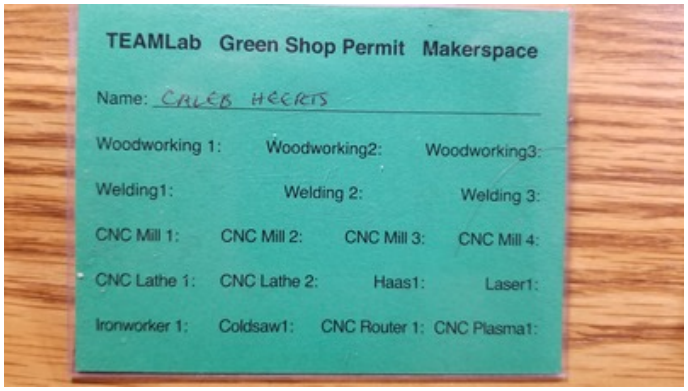
Content by: Caleb H

Goals: To document the completion of the Green Permit

Content:

Conclusions/action items: I have completed the Green Pass to be able to work in the lab for testing and development of our prototype.

Caleb Heerts - Oct 09, 2019, 1:49 AM CDT



greenpass.png(14.9 MB) - download

Caleb Heerts - Oct 09, 2019, 1:50 AM CDT

greenpass2.png(18.8 MB) - download

Cost Spreadsheet

Caleb Heerts - Apr 25, 2021, 4:01 PM CDT

No current costs :)
https://docs.google.com/spreadsheets/d/1wJrSKwXDXIq8nBryII5ASyP-XcRJz87ihQ7AbZbsNps/edit#gid=529386342
Item Description Manufacturer Part Number Date QTY Cost Each Total Link
Category 1
$0.00
$0.00
Category 2
$0.00
$0.00
TOTAL: $0.00

updated: 4/25/21

03/02/2021 - Recap of Research

Hunter Hefti - Mar 02, 2021, 1:40 PM CST

Title: Research Recap

Date: 03/02/2021

Content by: Hunter Hefti

Present: N/A

Goals: Establish precedent for research in the previous semester

Content:

In the last semester, a lot of initial research concerned the usage of the technology at hand. Specifically, flow cytometry was analyzed through the use of alternative designs to better understand such as a system of multiphotonic detection of fluorescent characterization with a cell sample [1]. This research coincided with research into the guidlelines surrounding the use of the technology for cell sorting with one article in particular going in depth into the different types of media and cellular interactions occuring within these types of devices [2]. A separate paper included instructions for attempting various types of inertial ordering methods [3].

Once the concepts behind flow cytometry were nailed down, research focus turned towards the several competeing designs. One proved so crucial that it will get its own journal entry following this one. An inertial ordering design called the soRT-FDC ship was looked at to reflect on the possibillity of adding sheath flow to aid in the focusing power of the inertial channel [4]. There were a few other interesting developments that this paper highlighted, including the use of an asymmetric channel to focus the cells into a single file line and the potential to fabricate the device from PDMS. Another method designed via soft lithography to sort cells via dielectrophoresis was described in a separate paper also using a similar design [5]. From research into the Reynold's number, it was determined that a certain combination, presently a 50um channel with a 9-10um particle, will have an optimal amount of focusing.

Conclusions/action items:

This research is all present in the former notebook and will likely not be observed in depth beyond that notebook.

[1]. D. G. Buschke, J. M. Squirrell, H. Ansari, M. A. Smith, C. T. Rueden, J. C. Williams, G. E. Lyons, T. J. Kamp, K. W. Eliceiri, and B. M. Ogle, “Multiphoton Flow Cytometry to Assess Intrinsic and Extrinsic Fluorescence in Cellular Aggregates: Applications to Stem Cells,” *Microscopy and Microanalysis*, vol. 17, no. 4, pp. 540–554, 2010.

[2]. https://onlinelibrary.wiley.com/doi/full/10.1002/eji.201646632

[3]. P. P. A. Suthanthiraraj and S. W. Graves, “Fluidics,” *Current Protocols in Cytometry*, vol. 65, no. 1, 2013.

[4]. A. A. Nawaz *et al.*, "Intelligent image-based deformation-assisted cell sorting with molecular specificity," *Nature Methods,* vol. 17, no. 6, pp. 595-+, Jun 2020, doi: 10.1038/s41592-020-0831-y.

[5]. P. Han, S. Yosinski, Z. A. Kobos, R. Chaudhury, J. S. Lee, T. M. Fahmy, and M. A. Reed, “Continuous Label-Free Electronic Discrimination of T Cells by Activation State,” *ACS Nano*, vol. 14, no. 7, pp. 8646–8657, 2020.

03/02/2021 - The DiCarlo Paper

Hunter Hefti - Mar 02, 2021, 1:43 PM CST

Title: Continuous inertial focusing, ordering, and separation of particles in microchannels

Date: 03/02/2021

Content by: Hunter Hefti

Present: N/A

Goals: Summarize parts of the paper that provide inspiration for the snake design

Content:

The main portion of the article focuses on the testing of an inertial ordering system in which flow orients itself central to the channel across the channel and lengthwise. A principle of centripetal forces with respect to curvature in a pipe can be described by the deans number. When a certain amount of symettrical curves are introduced, turbulent flow allows for the centering of stream lines to two separate flows with focusing becomin more complex as Deans number is increased. The asymetric flow system focuses the channel better twoards a central streamline. Expermentation with particules of 10um was induced to observe this effect and is shown in the figure below.

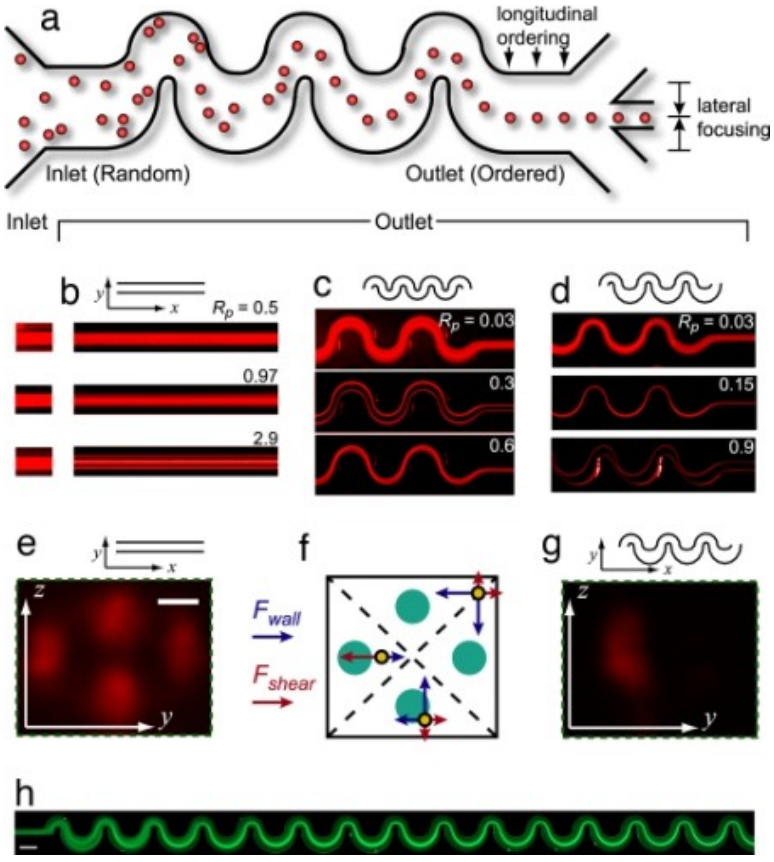


Figure 1. A compartive image of a rectangular channel, a symmetric curve design, and an asymmetric curve design as they focus cells down a channel.

The second figure included in this entry reflects the results of the experimentation with cell centering and compares the asymmetric design with a typcial flow through a rectangular channel. Results are observably different and reflect a positive aspect of hte inertial lift principle that is involved in straightening out the cells.

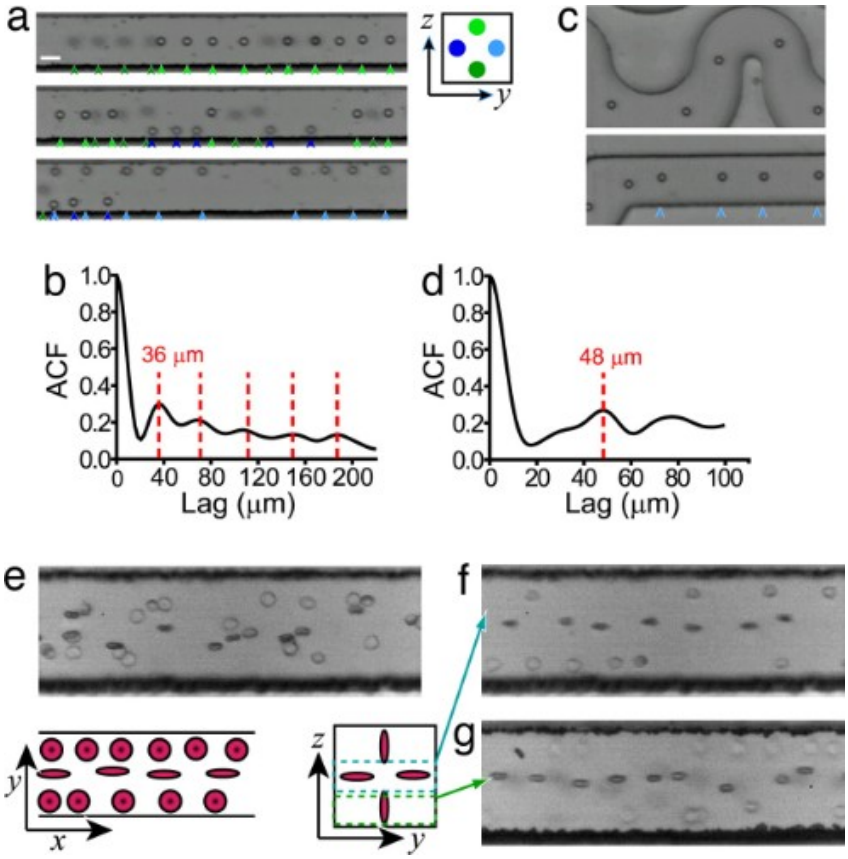


Figure 2. A comparision between the left's rectangular channel and the right's asymmetrical curve channel. Bottom images demonstrate the 10um cells as they pass through the outlet channel.

SU-8 master molds were generated using soft-lithography techniques followed by a PDMS pour which formed the inlet and outlet portions as well as the surrounding channel. The resulting device was plasma bonded to a glass slide for viewing under a microscope.

Conclusions/action items:

This experimentation is heavily noteworthy for functiionally centering the cells one at a time. Flow speed is unaccounted for, but the ability for Skala lab to vary flow velocities using the pump might imply an advantage towards this sort of design to aid in the focusing of cells down the channel.

This article has been exceedingly useful in determining the shape of the channel within our design. ImageJ was utilized to ge the precise dimensions when using a 50um channel and these dimesnions have been scaled in accordance with differen channel widths. This is a highly influential paper to the overall design and should be referenced frequently.

D. D. Carlo, D. Irimia, R. G. Tompkins, and M. Toner, “Continuous inertial focusing, ordering, and separation of particles in microchannels,” *Proceedings of the National Academy of Sciences*, vol. 104, no. 48, pp. 18892–18897, 2007.

02/02/2021 - Snake 7

Hur

Title: Snake 7

Date: 02/02/2021

Content by: Hunter Hefti

Present: N/A

Goals: Describe the seventh iteration of the snake design that was designed to help analyze the reynold's and dean's number.

Content:

This design was utilized to initially test the claim of the effectiveness of the reynolds number. It was a simple creation using the method of shelling an extruded subject. Once completed, the flu focusing power at higher velocities.

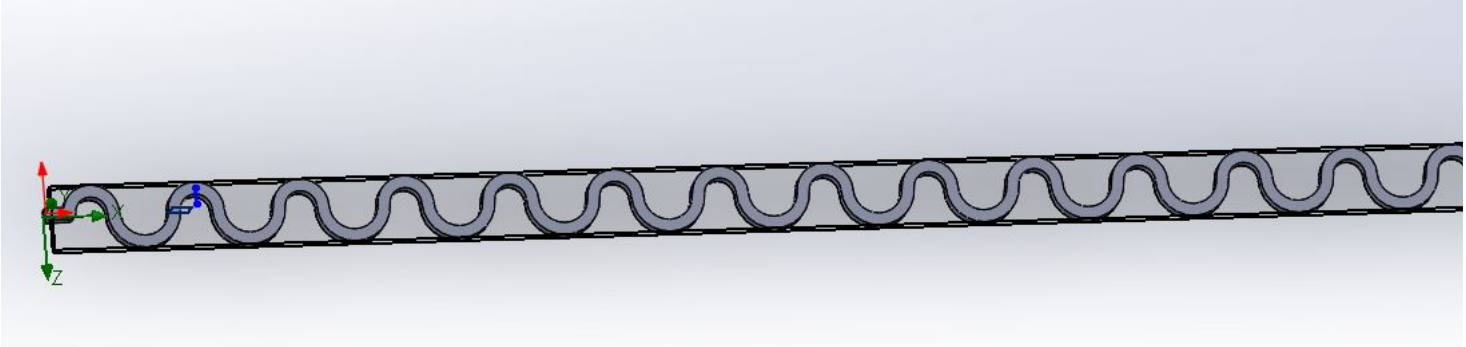


Figure 1. The Snake 7 design within its mesh.

Conclusions/action items:

The Snake 7 design was a work in progress for the snake 8 design.

02/14/2021 - Snake 8

Title: Snake 8

Date: 02/14/2021

Content by: Hunter Hefti

Present: N/A

Goals: Describe Snake 8 design

Content:

The Snake 8 design was attempted using the sweep function in which one face was created in place of the extrusion method. This was a much more streamlined way of making the snake and specifcation that the thickness no longer needed to vary. Snake 7 already used this concept but this was unusual as former methods for modelling the DiCarlo paper's design required varyatio from smaller to larger. Instead, just the turn radius was varied using a single line sketch and the specification for width was supplied with a singular rectangular sketch at the beginning.

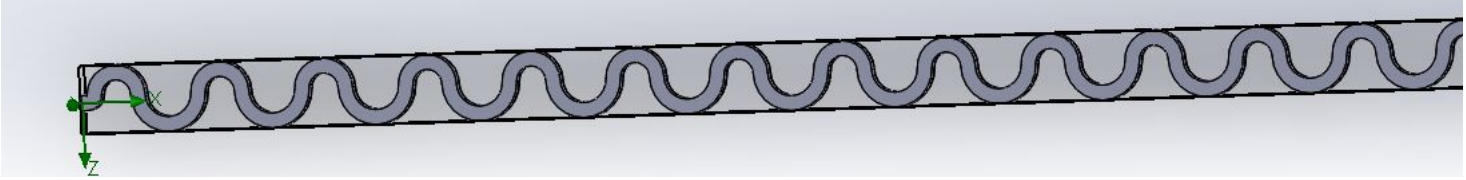


Figure 1. The 8th snake design with accompanying mesh. Intially attempt to utilize lids to run simulations resulted in error, but eliminating the need for lids by keeping the ends intact and using to run smoothly

Conclusions/action items:

The 8th snake paved the way for the scaled interpretations that follow

02/19/2021 - 100, 125, and 150um Snake designs

Title: The Initial Variants of the Snake

Date: 02/19/2021

Content by: Hunter Hefti

Present: N/A

Goals: Describe the three rescalings made for the client meeting next week

Content:

The new method of design proved effetive in terms of streamlining the process. Rather than taking an hour to design at new device at a time, it was taking about 15 minutes. Even simulation ti time spent running the simulation as designing the new device. Since Caleb assigned himself the task of creating the 50um design, I took on the task of scaling this up to 100, 125, and 150um that was put forth last semester.

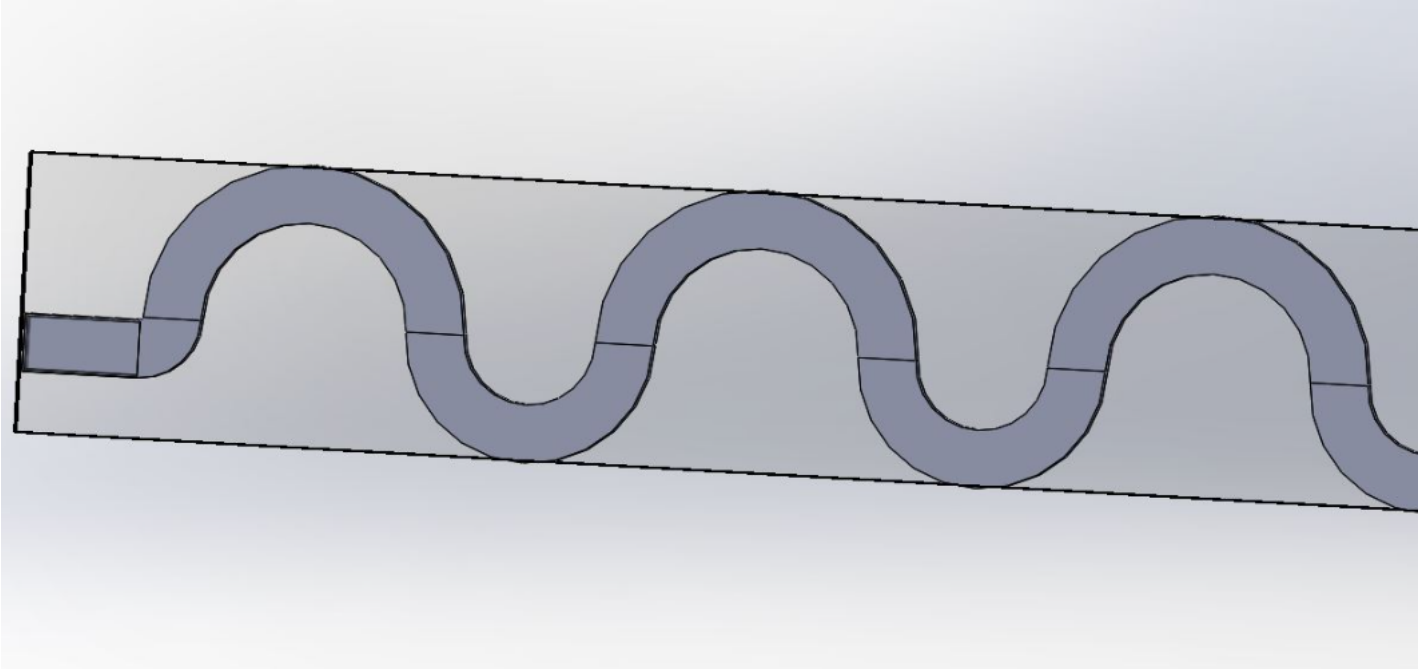


Figure 1. The 100um design was the only one which I ran a particle simulation on directly. The other designs had parameters assigned but the simulations were never officially run.

Interestingly, despite not varying the widths of the different curves, this design did actually seem to focus particles at raised speeds. Unfortunately, the client eventually overturned this design s occur.

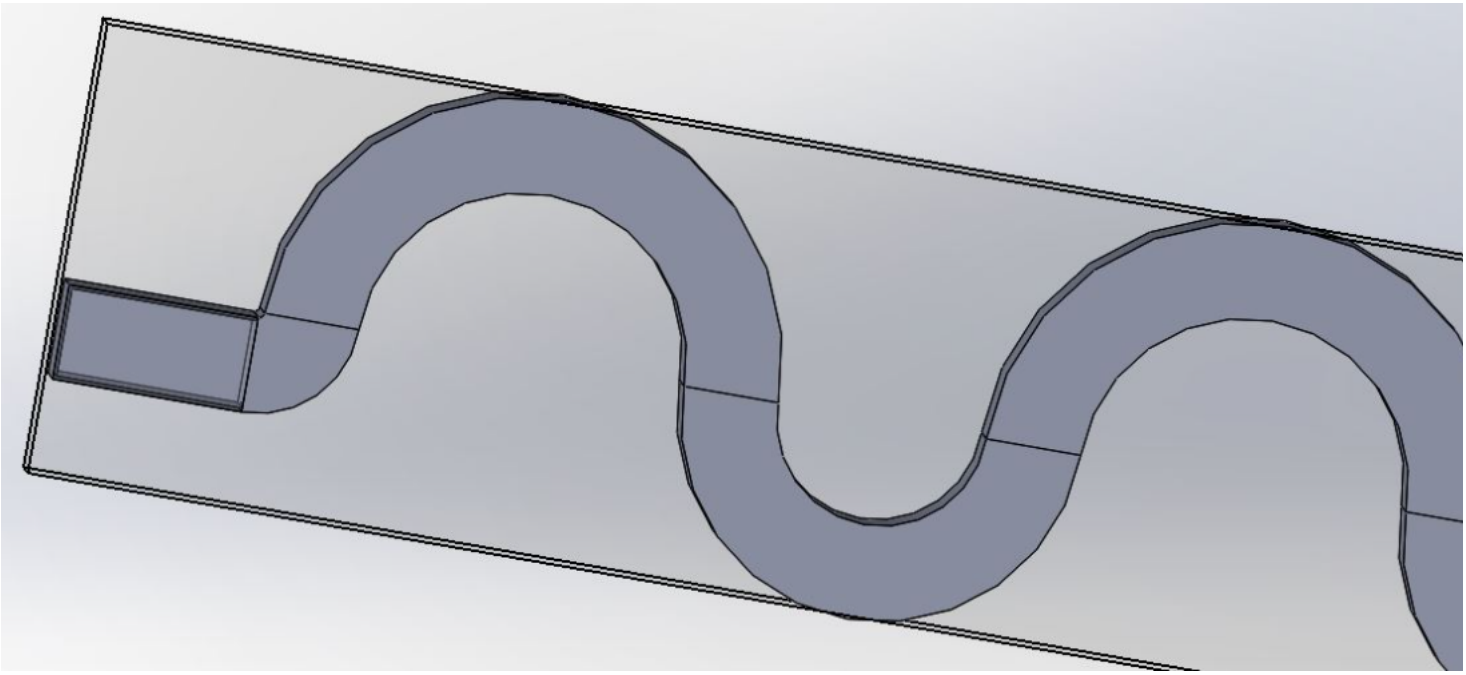


Figure 2. The 125um meter design features the same curve ratio but 1.25 times as large.

Conclusions/action items:

The client misspoke at the previous meeting which invalidates this more streamlined approach.

02/24/2021 - Redesigned 50um Snake

Title: Redesign of 50um Snake

Date: 02/24/2021

Content by: Hunter Hefti

Present: N/A

Goals: Describe the new redesign that I gave to Caleb to work on for next meeting

Content:

The latest design more closely resembles the work I was doing over the winter break. This design was created using the design specfially demonstrated in the DiCarlo paper and was made by dimensions and then shelled with a 5um wall on all sides. After completion, the design was handed off to Caleb for pressure testing and some scaling work to form the 100 and 125um channe

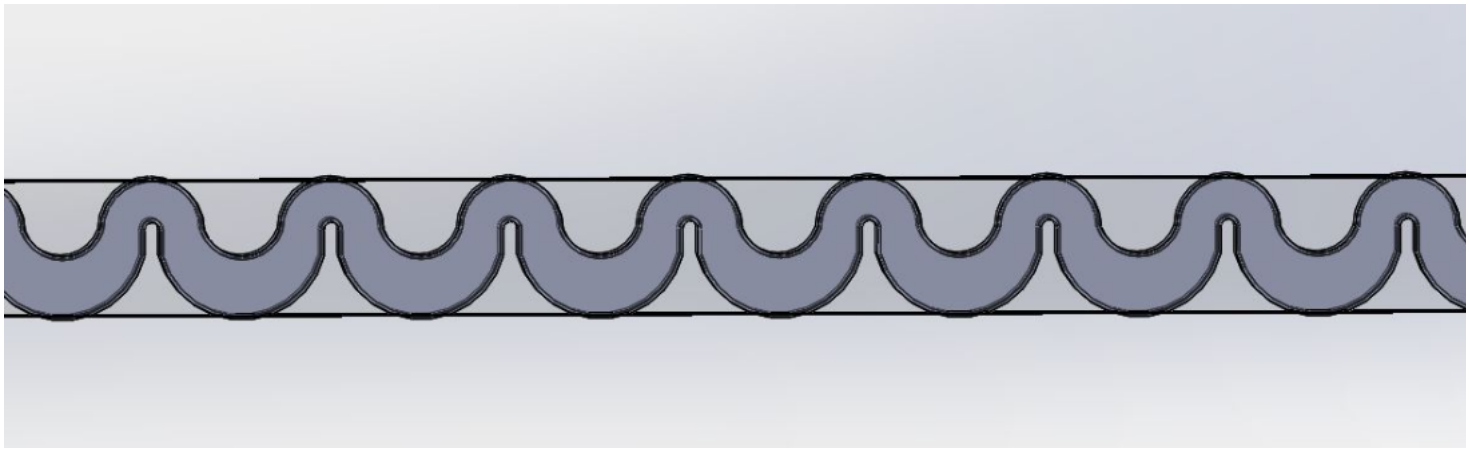


Figure 1. The 50um channel which conforms more to the original design.

Conclusions/action items:

This design should be expanded upon in the future to generate relevant data.

03/07/2021 - 100um Parametric Simulations

Hunter Hefti - Apr 21, 2021, 12:36 PM CDT

Title: 100um Parametric Simulations

Date: 03/07/2021

Content by: Hunter Hefti

Present: N/A

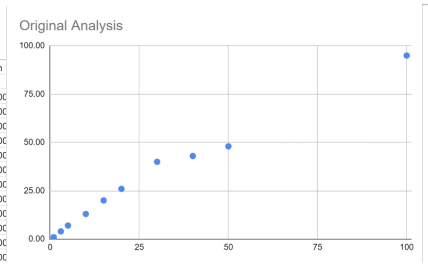
Goals: Talk about the first parametric simulations

Content:

Given the shear amount of simulations that needed to get done with varying input pressures, it was necessary to split work up and run a parametric study to achieve the amount of results that were required. Using my 50um redesigned channel, I scaled the design's sketch in SolidWorks and resized the channel to be 100um while Caleb scaled the entire design for an interior of 150um (originally intended to be 125, but Caleb misread and didn't learn of his mistake until much too late to redo the work) and Josh was given the already existing 50um design to work with (alongside his funnel design which had already been in progress since last semester).

So now that I had a 100um snake channel to work with, I needed to figure out how to do the proper simulations. Details will be written and followed up on in a new entry, but essentially I found a way to alter the input pressure automatically so that simulations would run without the need for automatic setup. The process still took multiple hours and put my laptop nearly out of service. But, at the end, we were able to develop a spreadsheet with all of the particle end velocities for a variety of input pressures (Josh started and added his data on March 3rd, I did mine on March 7th, Caleb on March 14th). This also revealed a great many pictures which were very illustrative of what this was capable of achieving

			Input from you	Change to mm
Pa	mBar	difference in mBar	m/s	mm/s
101325	1013.25	0	0	0.00
	1014.25	1	0.0010	1.00
	1016.25	3	0.004	4.00
	1018.25	5	0.007	7.00
	1023.25	10	0.013	13.00
	1028.25	15	0.02	20.00
		20	0.026	26.00
		30	0.04	40.00
		40	0.043	43.00
	1063.25	50	0.048	48.00
	1113.25	100	0.095	95.00
one	2013.35	1000	0.473	473.00



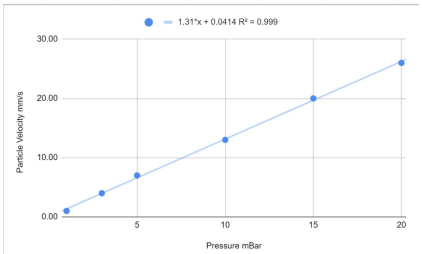


Figure 1. The above table and graphs represent the original parametric study using pressures of 1, 3, 5, 10, 15, 20 ,30, 40, 50, 100, and 1000 mBar. This initial test was run on every scale of the design and possesses the most data that accurately crosses over. This particular set of graphs is for 100um.

As seen in Figure 1, the velocity plots of the particles at the end of the channel for the 100um width are essentially linear at low pressures. This was actually obeserved with all channel widths but the extent to which this linearity continued was markedly different. For the 50um channel, the linearity lasted up through 100 mBar of pressure while it only lasted until 15 mBar for the 150um channel. Nonetheless, the extent to which these plots extened out towards the 1000 mBar max had not been observed so another parametric study would have to be initiated to find how this pattern was altered.

But velocity information was not all that was gleaned from the initial testing. As can be seen below in Figure 2, this was the first time that the effect of pressure could be seen on the particle stream itself.

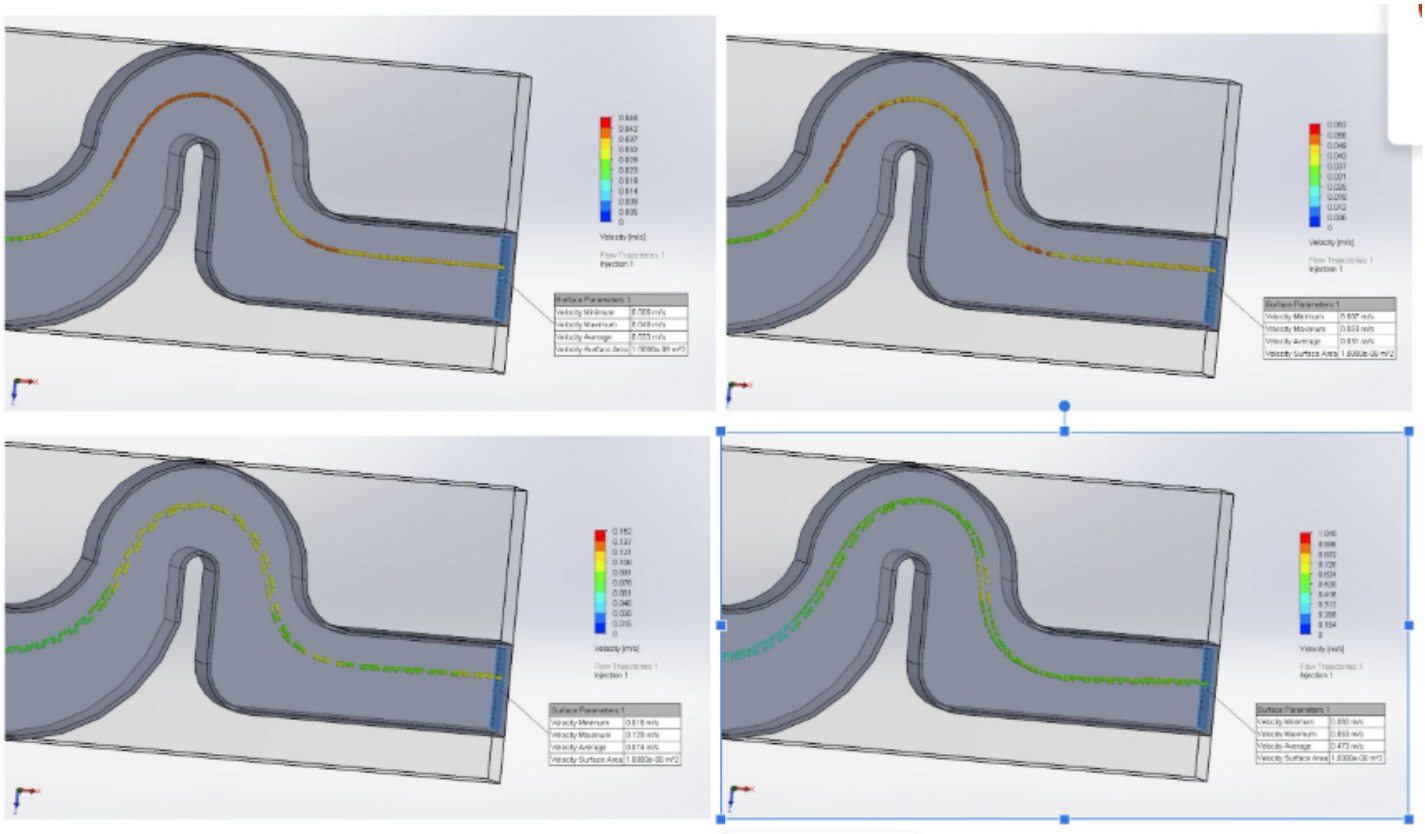


Figure 2. It is likely hard to make out using these images but further entries will likely make the problem clear. The above images show 30mBar, 40 mBar, 100 mBar, and 1000 mBar pressure simulations. At some point for the 100um snake, between 50 mBar and 100mBar, the stream splits into two distinct streams, much more concentrated and streamlined than the first stream, but, unfortunately, this means that there is an upper limit for the single file focusing at a certain amount of input pressure.

Conclusions/action items:

The parametric study introduced us to two new concepts. The first also has a form of conclusion in that we observe velocity changes between channel widths (smaller widths show better linear increase and slower end particle velocities than with much bigger channels), but also that this pattern needs to be observed further to understand how and why this velocity change occurs as pressure increases. The second is that there is an upper limit, also much higher for the smaller channel than the larger channels, at which central focusing diminishes and then splits into two streams, which would be useless for particle tracking using the method that Skala currently has employed. Two things need to be accomplished besides the currently set goals of measuring centering and velocity: we need to find an explanation for velocity changes, and we need to find the upper limit at which too much pressure splits the particle stream into two.

03/15/2021 - How the Parametric Studies were Run

Title: Parametric Studies

Date: 03/15/2021

Content by: Hunter Hefti

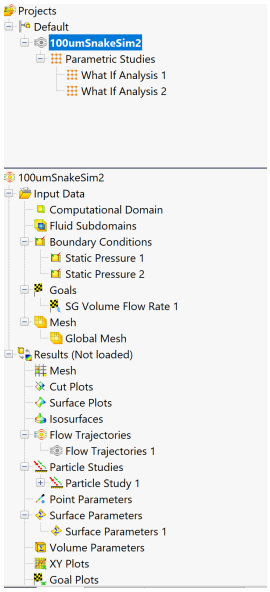
Present: N/A

Goals: Explain how to run parametric simulations

Content:

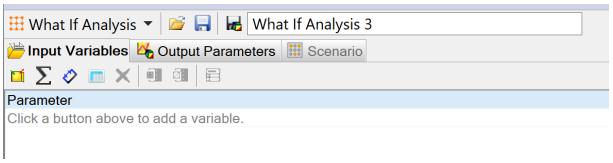
Background: Due to the fact that my laptop decided to crash and I had to buy a new one, I needed to instruct the other two on how to run parametric simulations. Caleb had not gotten around t process yet. So the following are the instructions I gave them while I was redownloading everything back onto my computer to run the expanded set of pressures:

Running the Study

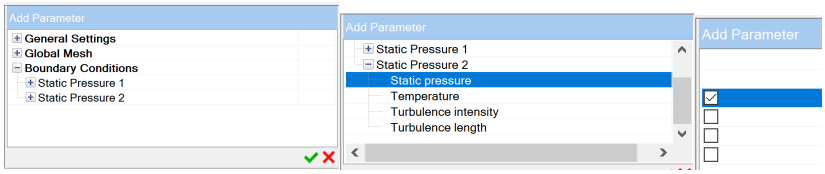


When starting a parametric study, you'll want a few parameters in place ahead of time. Both static pressures should be placed at either side (one set at atmospheric pressure and another set at a 1 mBar to in Rate should be set at the surface that has atmospheric pressure. With these in place, it helps to run a quick test to get the particle study set up ahead of time, so that everything is properly in place prior to the don't forget).

After right clicking the name of the study (highlighted in blue above), you will click "New Parametric Study" and a table will load in at the bottom of the screen which says "What if Analysis".



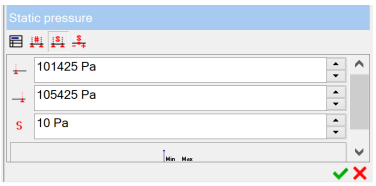
From here, click the first button just under "Input Variables" which prompts you to "Add Simulation Parameters". This opens the following tab in the lower right hand corner of the screen:



Once open, check the box for static pressure (for me, the input static pressure was set as "Static Pressure 2") so that the input is officially selected and press the check mark. This should reflect in the table:

Parameter	Current Value	Variation Type	#	Values
Static pressure (Static Pressure 2)	101425 Pa	Discrete Values	1	101425

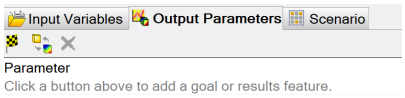
Next, right click on the "Discrete Values" and select "Edit Variation". This should pull up a new menu similar to the last. By clicking on the 3rd icon within the table, you should see a screen that allows you to in



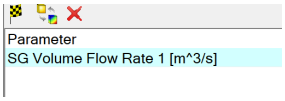
By clicking on the checkmark, the screen should be updated like this:

Parameter	Current Value	Variation Type	#	Values
Static pressure (Static Pressure 2)	101425 Pa	Range with Step	401	101425, 101435, 101445, 101455, 101465, 101475, 101485, 101495, 101505, 101515, 1015

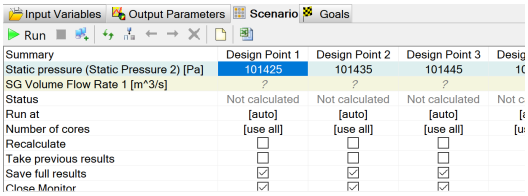
Next, you'll maneuver to output parameters and click on the checkered flag icon.



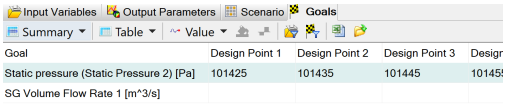
This pulls up yet another menu that lists all of the goals that you selected from the initial setup stage: in our case, only the Surface Goal will appear. Selecting this ensures that there is actually something to ru



Once this has been selected, the Scenario tab will update to show the following:



And a Goals tab will have appeared which displays the selected result (in this case, the surface goal. The surface goal for volume flow rate will appear inverted and can be used to calculate, manually, the ave simulations can run):



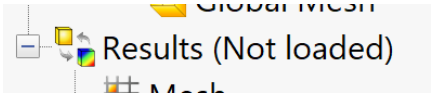
When all of this is displayed, you can return to the Scenario tab and click Run. This will launch the simulations to begin the calculation process which, when running correctly, will begin to look like this:

Design Point 14	Design Point 15	Design Point 16	Design Point 17	Design Point 18	Design Point 19
166325	171325	176325	181325	186325	191325
-3.47094326e-09	-3.65926297e-09	?	?	?	?
Finished	Finished	Calculating...	Not calculated	Not calculated	Not calculated
This computer	This computer	This computer	[auto]	[auto]	[auto]
8	8	8	[use all]	[use all]	[use all]
☐	☐	☐	☐	☐	☐
☐	☐	☐	☐	☐	☐
☑	☑	☑	☑	☑	☑
☑	☑	☑	☑	☑	☑

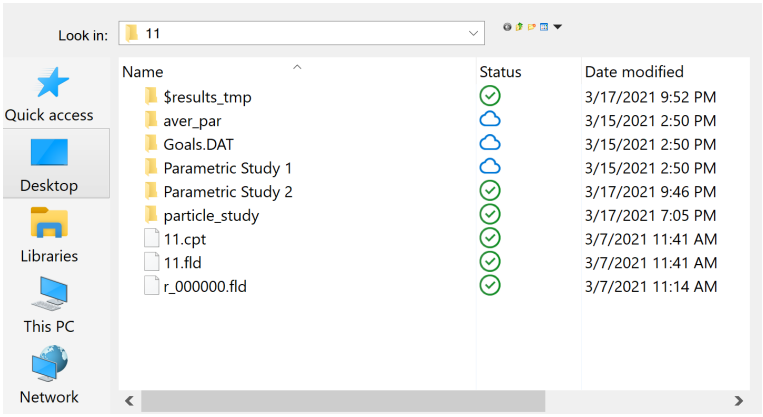
The speed at which iterations run is dependent on the amount of cores that are being used. My computer from last week was running with only 4, and the process of computing 12 Design Points took roughly total Design Points, and it only took 2.5 hours running on 8 cores. Either way, I left it alone both times and the process carries out automatically without the need to clone or manually reset the Static Pressure. the What if Analysis.

Loading the Results

Once the simulations complete, each result is preserved in a file folder saved to whatever your Solidworks has been told to save things to. So you can left click on the results tab and click "Load from File"

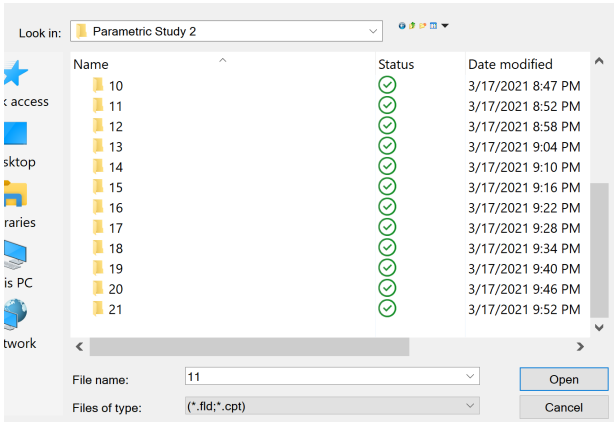


Upon hitting load from file, it should take you directly to the folder containing the information from that particular simulation automatically. If you ran a test run, a .cpt and .fld file will appear below the folders (n parametric study listed was for the original 12 data points while the recent Parametric Study 2 is today's 21 data point study.

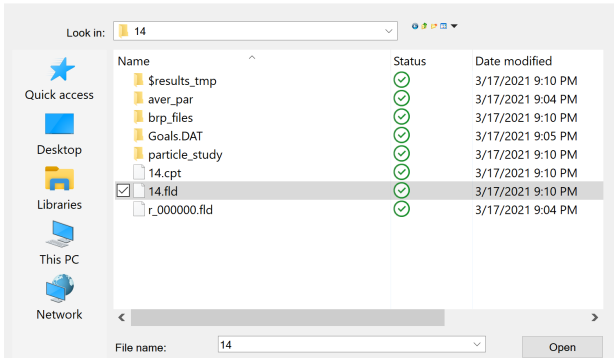


Also of note: the particle study. I usually set this up ahead of time, but it should not matter. In either case, once you set up a study, it will remain the same between file loads. So you should be able to casually

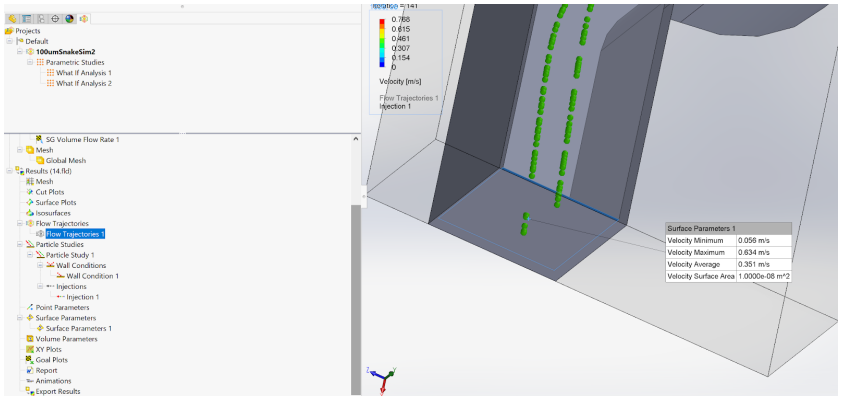
Upon clicking the new Parametric Study folder, numbered folders will appear in accordance with the number of data points. If you don't want to rename all of the folders, it is helpful to have the What if Analysi folder.



Opening any one of these folders will allow you to access another familiar looking folder setup (this whole thing is very Russian Nesting Doll, feels so unnecessary but what can you do). The important file that the respective simulation with that particular pressure, easy peasy. Any alterations can easily be observed if you look at surface speeds or just load in the particle simulation and load between the various folde



You should be able to switch between files even when the particle simulation is loaded in. That way the framing can stay consistent between shots when the particle simulation is paused. Additionally, (at leas speed of the particle by comparing the color and the average/max/min velocities to see what physically makes sense. In this case, the pressure far exceeds the cutoff for single file focusing, so two streams a velocity seems a better approximation, but, since these particles are very green, it's probably about 0.351m/s which is probably more accurate than just going with 0.307 from the legend).



Conclusions/action items:

It is likely that many of the images do not end up loading in the final notebook. I didn't want to have to reformat them so I jsut coppied and pasted all of it. This was done prior to our refocusing the final particle velocity. A further alteration came when Josh learned how to extract data onto Excell spreadsheets directly. This allows us to find particle trajectory information and parse throu workarounds. That being said, velocity info was mostly drawn from this method.

03/17/2021 - 100um Expanded Parametric Study

Hunter Hefti - Apr 21, 2021, 1:03 PM CDT

Title: The Expanded Study

Date: 03/17/2021

Content by: Hunter Hefti

Present: N/A

Goals: A shorter account of my experience with the expanded study and the 100um channel

Content:

Once I had my new computer (simulations ran 5x as fast now that I had more processing cores to work with at a given time), I began running more simulations using the SolidWork parametric study method I outlined in the previous entry. We settled on increments of at least 50 mBar (Caleb ran twice as many simulations with an increment of 25 mBar, an exercise that certainly proved fruitless given the results), so my 50 mBar entry was again repeated. The purpose of this study was to better generate an understanding of how velocity functioned at higher pressure inputs. Ultimately it appeared to be rather useful with regards to Josh's 50um design but for a rather unintended purposes. Observing velocity changes, we can refer to the images below.

		mBar			mm/s
101325	1013.25	0		0	0
106325	1063.25	50		0.048	48
111325	1113.25	100		0.095	95
116325	1163.25	150		0.14	140
121325	1213.25	200		0.175	175
126325	1263.25	250		0.2	200
131325	1313.25	300		0.22	220
136325	1363.25	350		0.233	233
141325	1413.25	400		0.25	250
146325	1463.25	450		0.267	267
151325	1513.25	500		0.29	290
156325	1563.25	550		0.311	311
161325	1613.25	600		0.331	331
166325	1663.25	650		0.351	351
171325	1713.25	700		0.37	370
176325	1763.25	750		0.388	388
181325	1813.25	800		0.406	406
186325	1863.25	850		0.424	424
191325	1913.25	900		0.441	441
196325	1963.25	950		0.457	457
201325	2013.25	1000		0.473	473

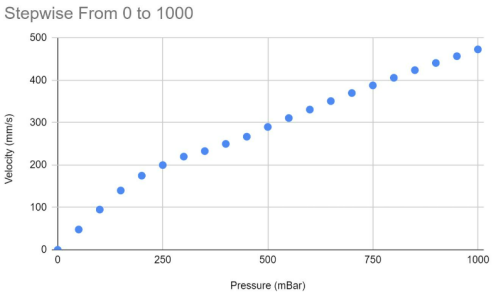


Figure 1. The table and graph associated with the 100um extended parametric study. Each data point represents a pressure increase of 50 mBar. Without the original study, it would have been impossible to tell that there was a sharper linear slope from 0-20mBar than exists here.

On my end, the 100um velocity study displays one crucial detail: there is still linearity involved in the velocity increase, the slope just changes after a certain pressure has been achieved. While this result could likley be analyzed further, the problem with looking at this graph is that, by the 3rd data point, the stream is no longer focused. And this is precisely what ended up being important about this study for the 50um channel. We learned that the particle stream fully split by about 200 mBar of input pressure.

Conclusions/action items:

While there is something interesting to note about the change in linear slope of pressure increase with velocity, all channels were no longer focusing their particles by the 200 mbar mark (ironically, this is where the change in slope happened on my velocity graph as well). This meant that the original data would be more important in identifying velocity as was relevant to the task at hand. All is not for nothing though, as this discovery of particle splitting meant that yet another task was presented in which I needed to identify the pressure at which my own 100um channel was no longer focusing into a single stream.

03/22/2021 - Finding the Split Point

Hunter Hefti - Apr 21, 2021, 1:38 PM CDT

Title: Finding the Split Point

Date: 03/22/2021

Content by: Hunter Hefti

Present: N/A

Goals: Describe the final round of parametric studies which were used to identify the 10 mBar range in which the particle beam split into two

Content:

By this point in the project, Sara's role as designer of the Outreach activity had been passed to me as I had established strong communication with my middle school. So I was planning for our outreach activity in the first week of April while maintaining my observations of particle focusing (having nearly lost interest in the role of velocity which was observed to follow a farily straighforward pattern that easily met hypothesized expectations). This left me with two projects, the first of which to be described in this entry.

With my new computer, it was much easier to run simulations at a faster speed. So I set up a quick parametric study for the space in between 50 mBar and 100 mBar to identify where the split was for sure being observed. While I could show an image to illustrate this, the results were much more useful and are shown easily in particle trajectory data instead (for future puposes, I resorted to only using 1-100 mBar with the occassional inclusion of 1000 mBar to illustrate the nearly stagnant nature of the split particle phenomena). To boil it down, there is a core flow velocity which was observed in my second project. At low pressures, the particle stream flows around this core, almost forming a parabola shape around the circumference. However, there is a sweet spot in which the inertial ordering is doing exactly as intended, for the 100um design this was found to be between 20-40 mBar. It is also at this point where the velocity of the particle can be approximated best by the maximum velocity of the flow through the channel. However, when the pressure is increased, the core velocity begins to interfere with the particle stream until, eventually, the stream splits into two. It is at this point that the particles appear to be most centered, but only because they are now at opposing sides of the core velocity, which typically remains centered for the duration (moving up and down depending on channel length). At this point, the velocity begins to drift towards being approximated by the average velocity.

The true and total split point of the particle stream appeared to occur at about just under 70 mBar, with completely single file lines of particles paired together. It was also at this point where the simulation showed its limitations, losing particles somewhere along the line to the point where the 4 center most particles had to be excluded as they merely disappeared somewhere within the channel.

Conclusions/action items:

The notion of a stream split point was an interesting find. Early research indicated that two streams would form if the snake's curves were symmetrically designed and assured that single file focusing could be achieved in asymmetric designs. So to learn that a dual stream can be achieved by increasing the pressure above a certain point was a striking revelations. For the 100um design, it implies that relevant data should be confined to a space below 70 mBar because, above this measurement, we are no longer focusing the particles in the intended way. More details of these revelations can be found from the cross-sectional observations.

03/22/2021 - Cross Sectional Image J analysis

Hunter Hefti - Apr 21, 2021, 6:40 PM CDT

Title: Cross Sectional Analysis

Date: 03/22/2021

Content by: Hunter Hefti

Present: N/A

Goals: State secondary accomplishments when analyzing the the causes of the split

Content:

Prior to the discovery of particle tracing techniques (or rather, tangentially to Josh's discovery that you can export SolidWorks data files), the main method for identifying how well the particles were centering was through ImageJ analysis of the raw Solidworks images. As was mentioned in the previous entry, this methods was greatly helpful in identifying how the particle streams were behaving and why...especially when the location of the particles was analyzed simulatenously with flow velocity surface maps at the end of the snake channel. Viewing the end of the channel head on (with the Z axis on the bottom and the Y axis on the right) one can view both the fate map and the velocity map side by side as can be seen in the comparisons below.

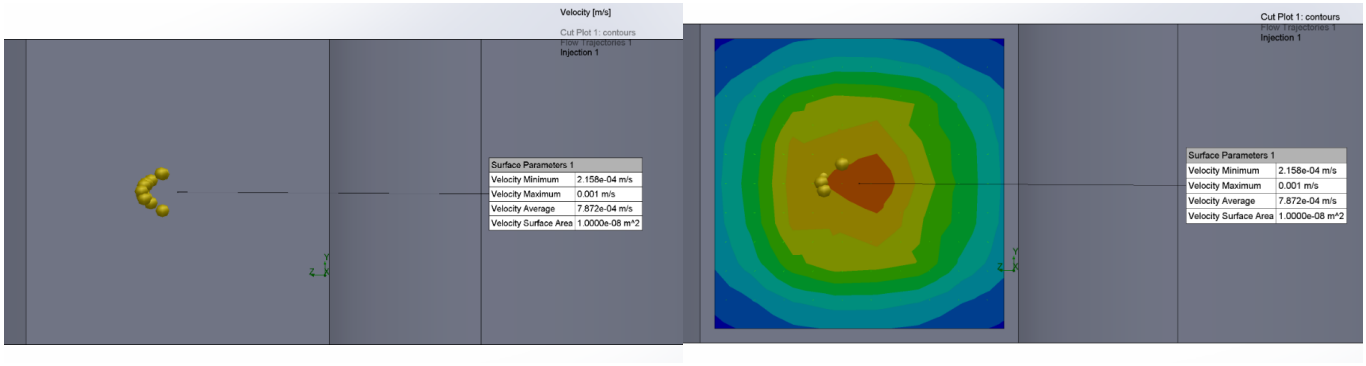


Figure 1. The input velocity for this set of images is 1 mBar. Already, it is clear from the image on the right, that a higher velocity is present nearing the center of the channel. At low pressure, the particles are essentially riding the bottom of the core flow velocty stream and possess a velocity that is slower than the max but not quite average (closely approximated by the green color).

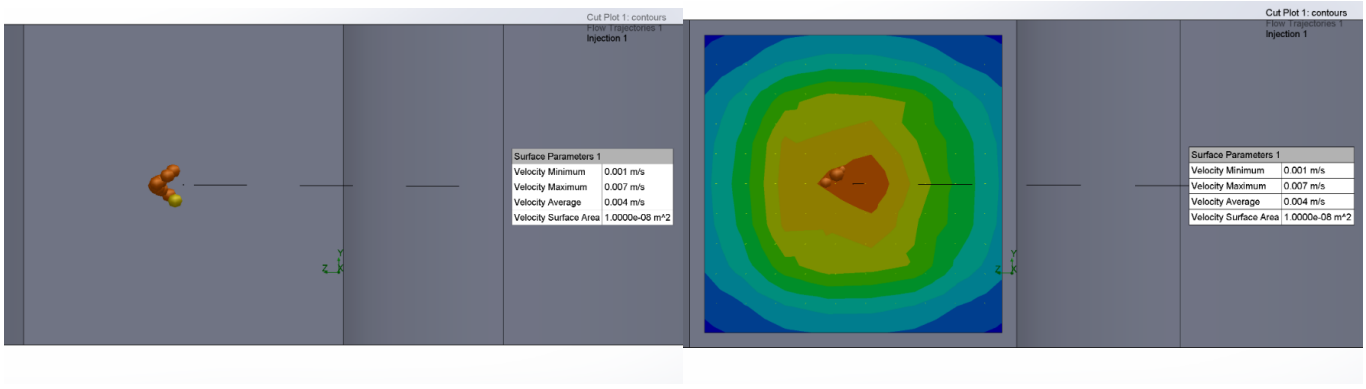


Figure 2. By 5 mBar, the particle stream has begun to merge with the core. This allows us to more closely approximate the particle velocity as the reported maximum velocity.

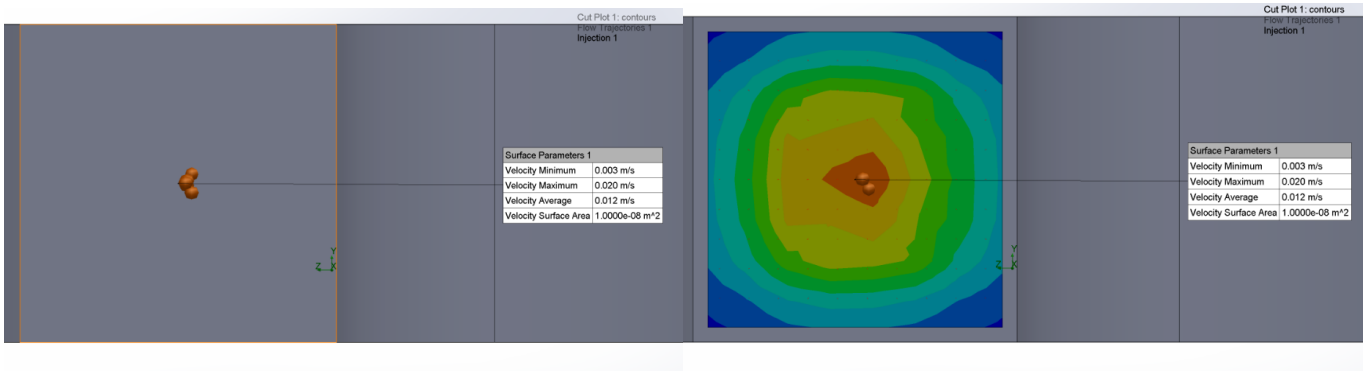


Figure 3. At 15 mBar, the particle stream is at approximately the center of the channel and subsequently the particle stream is equivallent ot the maximum velocity of the flow at the core (i.e. approximately 20 mm/s.

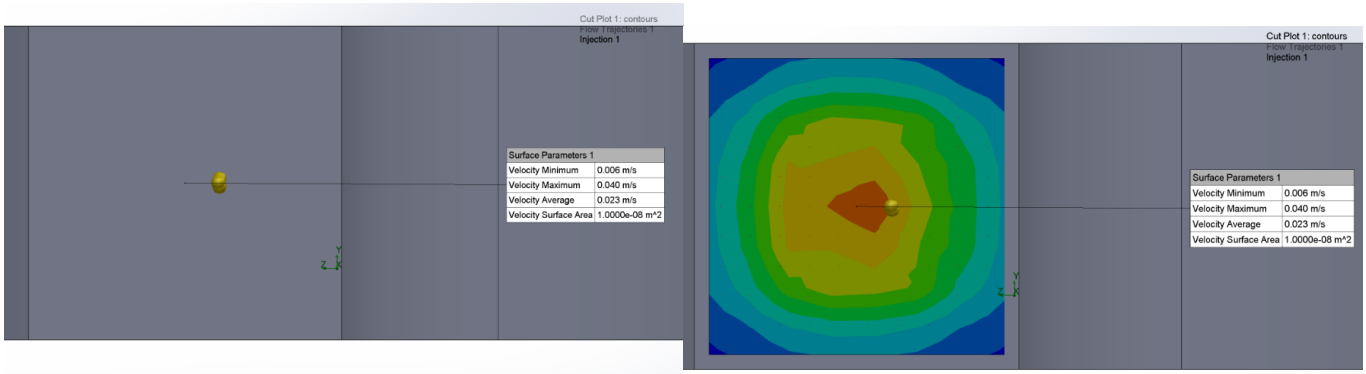


Figure 4. The transition from 20-40 mBar (30 shown) marks the streams gradual pass through the top of the core. The velocity can no longer be approximated by the maximum velocity and must be directly measured using the exported data. It is worth noting that this is also the location of the inital slope change in the velocity graph from the original parametric study, a much slower climb in velocity speed as the particle stream moves out of the core.

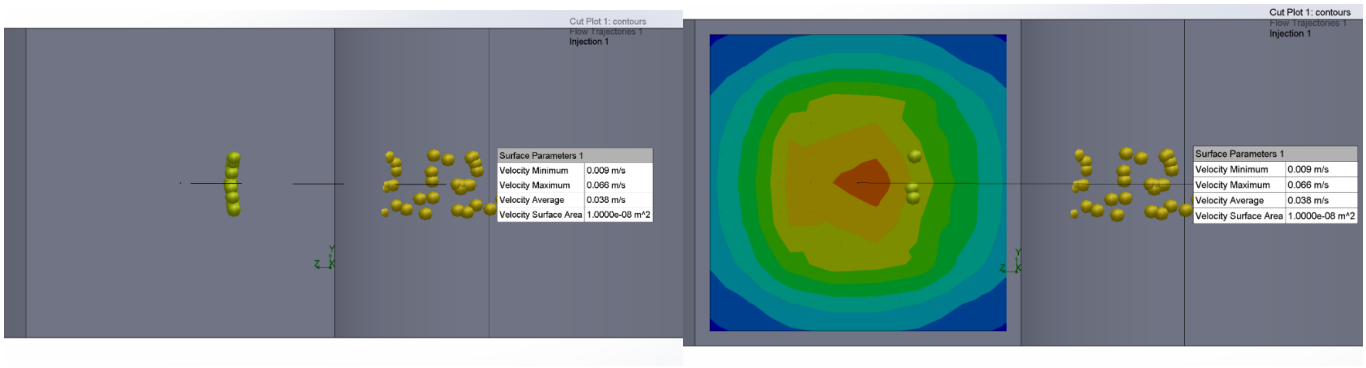


Figure 5. At 50, there is much more distance from the center and the centering is much more clearly ceasing to have the intended effect. Approximating the velocity shows a much clearer transition to the average flow velocity as the particles near an optimal route to deal with the increasing pressure.

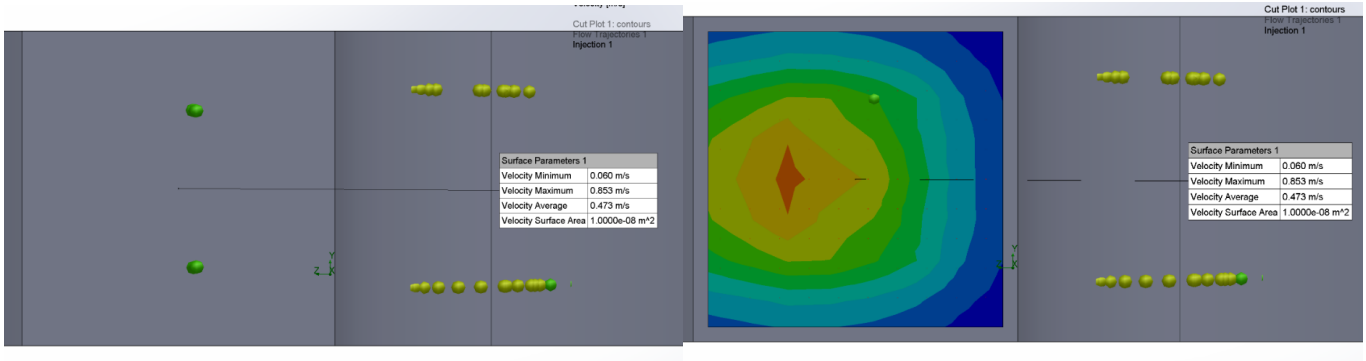


Figure 6. The above image is from the maximum velocity that was tested. Starting at approximately 70 mBar, the stream splits off into two distinct single file lines which is a result that remains mostly stagnant until 1000 mBar.

It can also be seen that the surface velocity map has changed drastically, with the core distorting and moving towards the left (bottom of the channel). While this is a clear impression of what increase pressure has as an effect on the velocity (its much higher but the particle speed can be reliably predicted by the average flow speed in the chamber now), the gradual movement of the particle stream upwards while the maximal core velocity moves downwards is likely indicative of an eventual collapse of the stream onto one of the walls (an estimation later confirmed by Caleb's Long Boy experiment demonstrating the flows increased distance down a linear channel and the creeping effect/tendency for the particles to slowly move towards one wall or another on the Z axis).

Conclusions/action items:

It is likely then that lower pressures still allow for the greatest amount of control and, from this emprical data alone, a recommendation of 15-30 mBars ought to suffice for maximum efficiency. But as this was not sufficient numerical data and the subject was merely to establish correlations between pressure and velocity, more numerical data needed to be collected to ensure that any emprical observations about the suggested simulation particle trajectory was accurate.

04/05/2021 - Particle Trajectory Graphs

Hunter Hefti - Apr 21, 2021, 7:44 PM CDT

Title: Particle Trajectory Graphs

Date: 04/05/2021

Content by: Hunter Hefti

Present: N/A

Goals: Relay information gained from initial attempts to graphically represent the particle trajectory.

Content:

In trying to find the best method to graphically represent the trajectory, Josh discovered how to extract data directly from the SolidWorks simulation file. This was incredibly helpful, but ended up generating excel spreadsheet files that were so large that, even with the increased processing power of my new laptop, having more than one spreadsheet open at a given time caused the entire system to crash and reboot. So playing around with this data seemed to be an insurmountable task. Luckily, the exported file does include preconstructed graphs regarding the trajectory of Y and Z. So while this does not entirely represent what the path of the particle looks like, it does give an interesting insight into the splitting pathway from a numerical point of view. To reduce the amount of pictures that need to get pasted, I will show the graphs regarding 1 mBar, 30 mBar, 60 mBar 70 mBar, and 90 mBar to illustrate the look of this information.

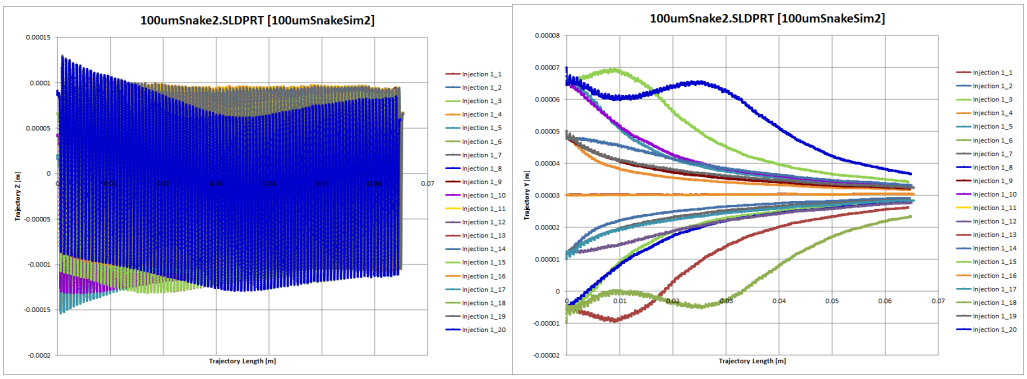


Figure 1. The 1 mBar shows a baseline of the smallest amount of pressure that was tested for. You can easily see on the Y graph (on the Right) that 4 particles from 5 distinct Y positions are merging towards a central focusing point.

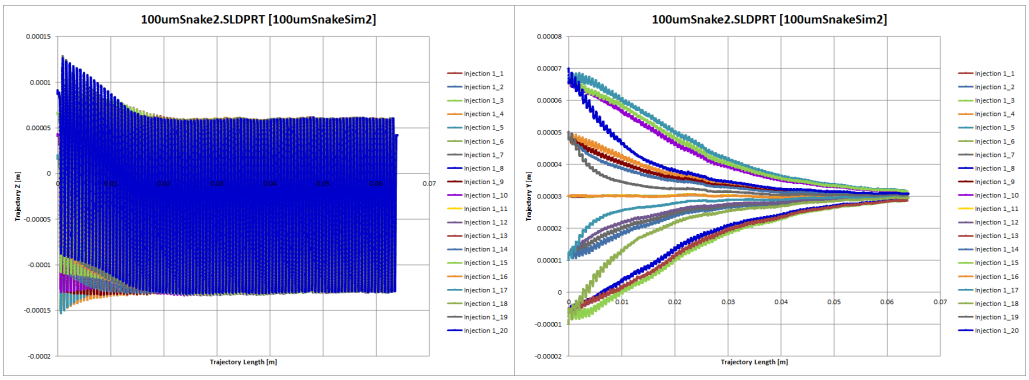


Figure 2. For the most centralized particle stream, the Z axis remains quite tight while the Y axis shows evidence of clear centering.

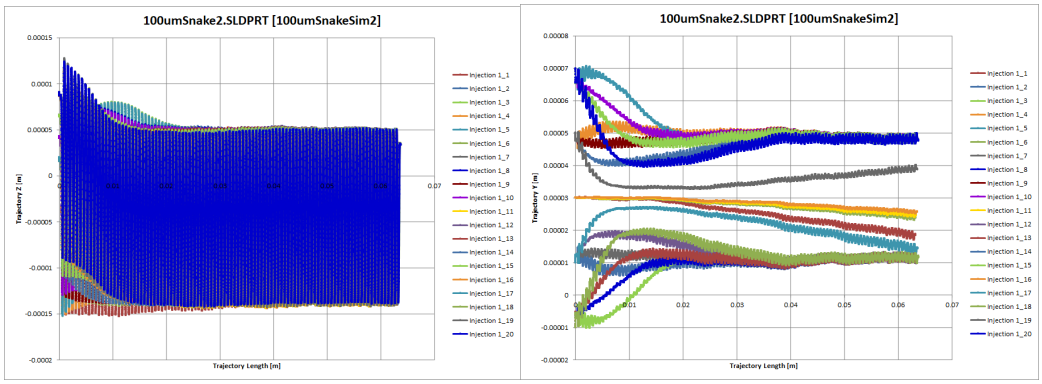


Figure 3. The 60 mBar of pressure that is now present demonstrates how the particles have become decentralized and begin to form separate streams.

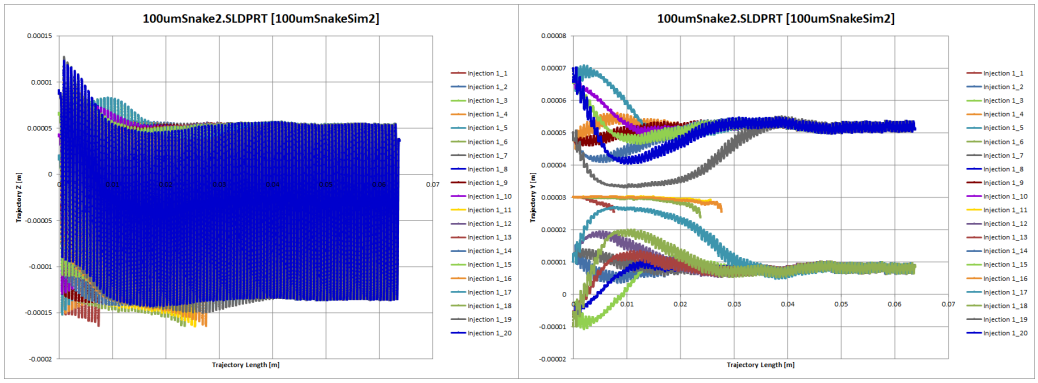


Figure 4. It is here, at 70 mBar of pressure, that we finall begin to see the two distinct streams being formed. It is also here that we are able to visualize our last great problem with the simulations: the middle four particles are not reaching the end of the channel and are not merging into either of the two particle streams.

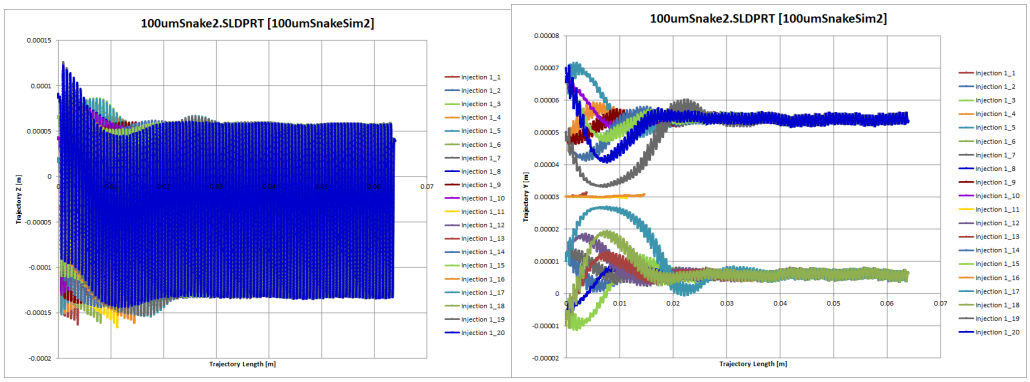


Figure 5. At 90 mBar, we have a clear visualization of the two streams as well as the failed four particles from the central position. This trend continues for the remainder of the pressures that were simulated.

At all points it is important to notice that only the Y axis provided any useful information. The graph of the Z axis remained fairly consistant throughout, only relaying a gradual merge of the points towards the same Z axis as pressure increased from 0. Unfortunately, while this information is certainly interesting, there is no way to methodically analyze it through statistical means.

Conclusions/action items:

The final round of analysis would have to consist of parsing through multiple rounds of injections to find which particles, near the end of the channel, would accurately represent the position of the particles at a cross-section of the focused stream.

04/18/2021 - Particle Tracing

Hunter Hefti - Apr 21, 2021, 9:15 PM CDT

Title: Particle Tracking

Date: 04/18/2021

Content by: Hunter Hefti

Present: N/A

Goals: Analyze the methods used to obtain the data regarding a final cross-section of the particle streams

Content:

Over the past week, much time has been spent preparing and finalizing the Outreach deliverables from the previous week. That being said, Josh attempted to put together some Matlab code (which he will likely detail in his own notes if that proved useful) that would easily parse through the 10000 or so rows of data points that resulted from the 20 injection particles. Unfortuantely, due the contraint of no longer having Matlab downloaded to my computer, I had to go through manually and sort through the particle data to get that data by hand. This process was significantly reduced by having the ability to control+f for the injection number and then take the final data point from the previous injection (Injection 1_3 would take me close enough to find the necessary point from Injection 1_2).

By doing this for every relevant simulation from 1-100 mBar and 1000 mBar, I was able to compile the starting and ending trajectory positional points for each of the 20 particles that were simulated between each reiteration. From this data, a particle tracking graph could be generated that would essentially accomplish the same goal for visualizing the location of the particles in space as the cross sectional images from a few weeks back. On top of this, histograms of the particle distributions over the Y and Z axis could be compiled and viewed side by side to demonstrate more clearly how the particles were being focused with the different pressures. Examples of 1 mBar, 30 mBar, and 70 mBar are shown below in Figure 2.

Figure 1. The initial position of all of the points. The horizontal axis represents the Y axis while the vertical axis is the Z axis. Due to the way that the channel was designed and resized, the center of the face is located at approximately (3E-05, 5.34E-05). Since these plots were created using the raw data, all of the numbers have not been converted to um yet and thus this is presented in terms of meters.

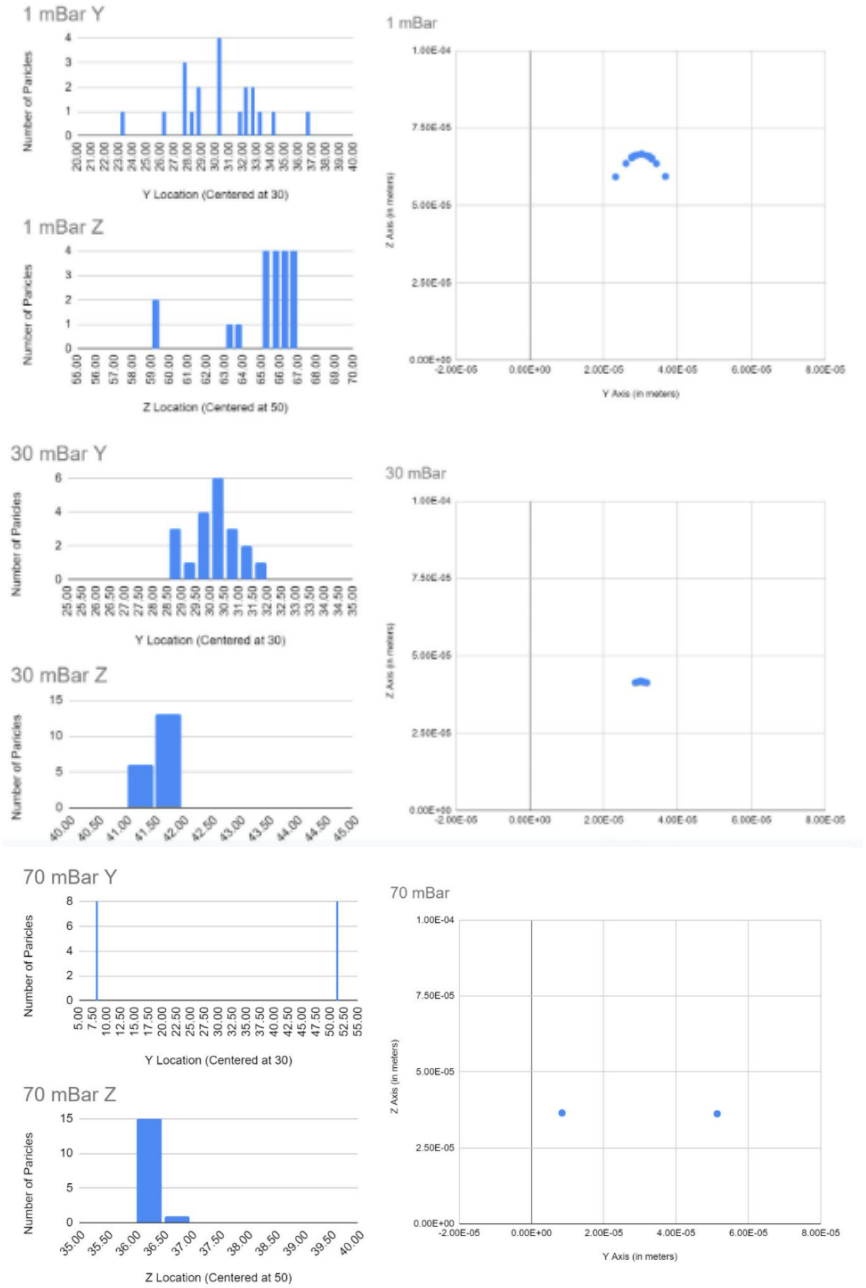


Figure 2. A graphical representation of the resulting data with histograms depicted in um and particle tracking depicted in meters. These graphs show essentially the same information as the cross sectional images, but, this time, there is an opportunity to actually analyze the information.

Conclusions/action items:

With the numerical data readily available, there is now the opportunity to test for the actual properties including standard deviations and the distance from the center that each of these particle streams is achieving. There may even be room for tests of statistical significance.

04/19/2021 - Analysis of Particle Tracing

Hunter Hefti - Apr 21, 2021, 10:01 PM CDT

Title: Analysis of the Data

Date: 04/19/2021

Content by: Hunter Hefti

Present: N/A

Goals: Analyze numerical data from before to get start noting what the various pressures are actually managing to achieve for particle focusing

Content:

Despite an initially incorrect assumption that the Z axis channel was centered at 50um (now informed by the initial particle positioning that this is approximately 53.4um instead), a few statistical data points were extracted from the individual sets of particle position data. The average center point of each axis was determined using the initial particle locations (which were found to be consistant across all simulations). Below are the detailed tables displaying standard deviations, averaged centers, range of particles on a given acess, and the distance from the channel center.

	Center (Average) Y	Center (Average) Z	St Dev Y	St Dev Z	Distance from Center		all numb
Channel Center	3.00E-05	5.34E-05	null	null	0.00E+00		
Initial	3.00E-05	5.34E-05	2.90E-05	2.87E-05	0.00E+00		
1 mBar	3.02E-05	6.50E-05	3.11E-06	2.14E-06	1.16E-05		
3 mBar	3.01E-05	6.34E-05	2.65E-06	2.28E-06	1.00E-05		
5 mBar	2.97E-05	6.15E-05	2.17E-06	2.01E-06	8.08E-06		
10 mBar	2.95E-05	5.69E-05	1.20E-06	9.72E-07	3.55E-06		
15 mBar	3.01E-05	5.05E-05	1.15E-06	5.98E-07	2.90E-06		
20 mBar	3.00E-05	4.72E-05	9.05E-07	3.77E-07	6.16E-06		
30 mBar	3.01E-05	4.16E-05	8.73E-07	1.55E-07	1.18E-05		
40 mBar	3.00E-05	3.89E-05	1.95E-06	5.34E-07	1.45E-05	Last Clear Centering	
50 mBar	2.94E-05	3.48E-05	6.43E-06	4.67E-07	1.86E-05		
60 mBar	2.82E-05	3.32E-05	1.64E-05	1.36E-06	2.03E-05		
70 mBar	2.99E-05	3.64E-05	2.21E-05	1.42E-07	1.70E-05	Clear Split in Stream	
80 mBar	3.00E-05	3.80E-05	2.37E-05	1.66E-07	1.54E-05		
90 mBar	2.98E-05	3.93E-05	2.44E-05	3.14E-07	1.41E-05		
100 mBar	2.99E-05	3.98E-05	2.46E-05	1.55E-08	1.36E-05		
1000 mBar	2.98E-05	4.67E-05	2.82E-05	1.89E-07	6.71E-06		

in um	30 um in Y	50 um in Z	St Dev Y	St Dev Z	Distance from Center	
Initial	30.00	53.39	29.02	28.68	0.00	
1 mBar	30.25	65.03	3.11	2.14	11.64	
3 mBar	30.07	63.41	2.65	2.28	10.02	
5 mBar	29.71	61.47	2.17	2.01	8.08	
10 mBar	29.45	56.90	1.20	0.97	3.55	
15 mBar	30.15	50.50	1.15	0.60	2.90	Closest to Center Point
20 mBar	29.98	47.24	0.90	0.38	6.16	
30 mBar	30.09	41.56	0.87	0.16	11.83	Smallest St Dev both Y and Z
40 mBar	30.04	38.91	1.95	0.53	14.48	Last Clear Centering
50 mBar	29.44	34.80	6.43	0.47	18.60	
60 mBar	28.18	33.19	16.41	1.36	20.28	
70 mBar	29.90	36.36	22.15	0.14	17.04	Clear Split in Stream
80 mBar	29.99	38.01	23.65	0.17	15.39	
90 mBar	29.84	39.31	24.44	0.31	14.08	
100 mBar	29.86	39.80	24.65	0.02	13.59	
1000 mBar	29.85	46.69	28.19	0.19	6.71	

Figure 1. The above displays the collected averages, standard deviations, and calulcated distance from the center for each of the provided input pressures, with the table on the right having converted those values to um. From these tables, we can observe where the closest particles are to the center as well as how compact they are via standard deviations with 15 and 30 mBar winning in each of these respective categories.

	Range in Y (um)	Range in Z (um)
1 mBar	13.48	7.38
3 mBar	12.66	7.77
5 mBar	10.27	6.72
10 mBar	6.14	3.55
15 mBar	6.50	2.10
20 mBar	4.68	1.40
30 mBar	3.16	0.42
40 mBar	7.46	1.70
50 mBar	18.86	1.33
60 mBar	36.45	3.30
70 mBar	42.90	0.29
80 mBar	45.81	0.34
90 mBar	47.34	0.62
100 mBar	47.75	0.05
1000 mBar	54.60	0.37

Figure 2. The above figure displays the ranges of data points that are present on the Z and Y axis where 30 mBar once again proves that it is the most condensed.

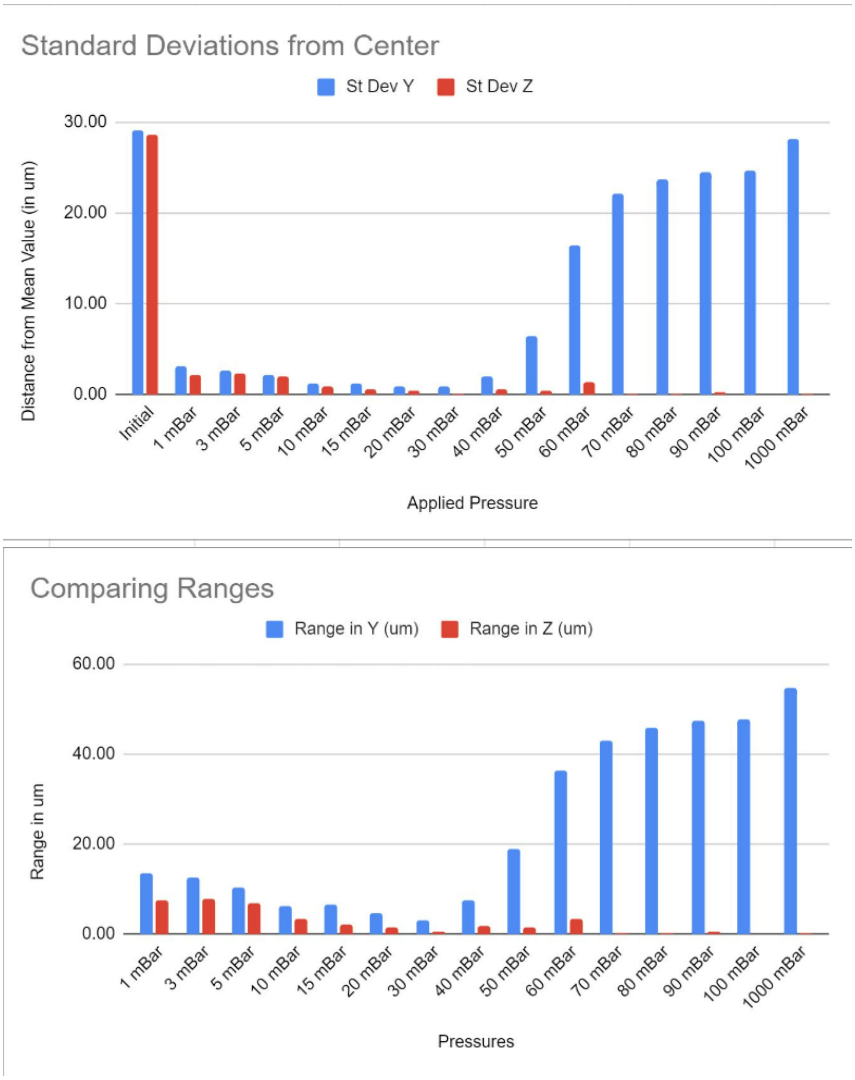


Figure 3. These graphs represent the standard deviations and the ranges of the Y and Z axis positions. They both demonstrate similar shapes which demonstrates the simulations accuracy with portraying particle centering.

Conclusions/action items:

While it would be nice to run a more enhanced statistical analysis of this data, the use of simulations implies that centering data is limited to a single replicate with no chance for error. Even when comparing two data sets, it is nearly impossible to qualify whether statistical significance is actually present (just running stats on simulations alone seems obtuse and bound for failure). While I will continue developing ways of showing the normalacy of the data at early stages and may run a significance test against varying data sets, it is my firm opinion that our inability to access the prototype that Skala lab developed back in Februrary has been a detriment as collecting multiple data replicates would be useful in determining whether such statistical tests were reliable determinants or not.

10/04/2020 - Biosafety Training

Hunter Hefti - Oct 04, 2020, 12:59 PM CDT

Title: Biosafety Training Documentation

Date: 10/04/2020

Content by: Hunter Hefti

Present: N/A

Goals: Establish existing biosafety training documentation that will allow me to work in general bio labs

Content:

Biosafety Required Training	Biosafety Required Training Quiz	2/25/2019	

Data Effective: Mon Feb 25 16:04:25 2019
Report Generated: Mon Feb 25 20:52:31 2019

Conclusions/action items:

Expires after five years or upon Wiscard Expiration, neither of which take place during the current semester.

03/01/2021 - Bloodbourne Pathogen

Hunter Hefti - Mar 02, 2021, 9:04 AM CS

Title: Bloodborne Pathogen Training

Date: 03/01/2021

Content by: Hunter Hefti

Present: N/A

Goals: Establish current training for bloodborne pathogens, granting permission to work with blood in designated lab spaces

Content:

BIOSAFETY 102: BLOODBORNE PATHOGENS FOR LABORATORY AND RESEARCH	BLOODBORNE PATHOGENS SAFETY IN RESEARCH QUIZ 2019	11/21/201

Conclusions/action items:

The training has been renewed as of 03/01/2021.

10/04/2020 - Green Pass

Hunter Hefti - Oct 04, 2020, 1:02 PM CDT

Title: Green Pass - Team Lab Certification

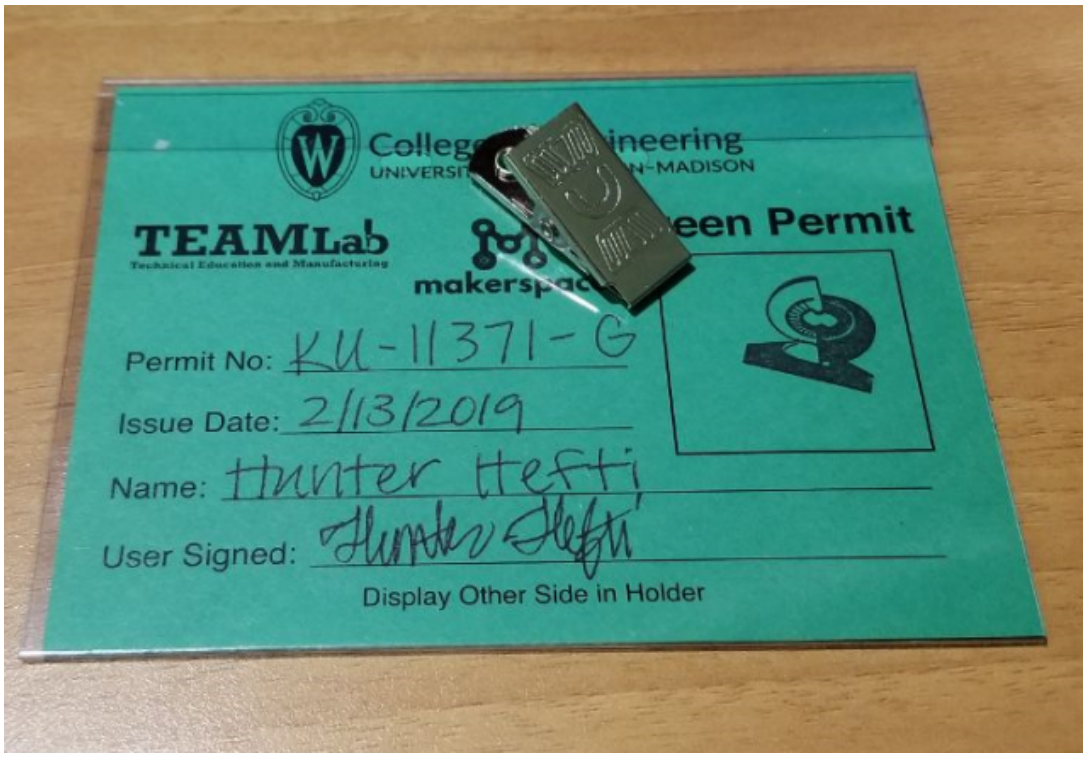
Date: 10/04/2020

Content by: Hunter Hefti

Present: N/A

Goals: Establish current training allotments with the Team Lab in the basement of ECB (which is no longer in existance)

Content:



Conclusions/action items:

This also has no set expiration date, but I am limited to the use of only a few machines in the team lab. If welding or some advanced form of machine is needed, more training must be acquired.

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items:

BME Design 2020 Fall notebook

Josh Zembles - Feb 03, 2021, 12:47 PM CST

BME Design-Fall 2020 - Josh Zembles
Complete Notebook

PDF Version generated by

Josh Zembles

on

Dec 09, 2020 @ 01:33 PM CST

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