Lab 2

Engineering 1282.02H

Spring 2020

Y4

C. Wallwey GTA MWF 12:40PM

Date of Submission: 2/28/2020

INSTRUCTIONS:

- Complete this worksheet as you complete Lab 2.
- Type all written responses/calculations as necessary.
- Include a title page, and properly format any figures or tables with appropriate titles, captions, units, etc.
- Check formatting of this document after completion, as page breaks will move as you fill out the worksheet.
- The Excel sheet on Carmen ('APP_N08_Lab_2_DATASHEET') containing the empty data table will automatically generate plots for you under the appropriate sheets. You may copy these plots into the designated places below, but **make sure you understand what the plots are showing you**. You may need to separate the average and maximum shear stress and velocity plots for scaling purposes. The spreadsheet also contains a formatted table for the results of your sensitivity analysis, which will also create plots for you. Be sure that any plots you include are formatted appropriately and easy to read (axes, legends, units, etc.).

Flow Rate Experiment:

1. Provide sample calculations for the following:
    a. Experimental flow rate
    b. Experimental pressure
    c. Wall shear stress based on experimental flow rate
    d. Wall shear stress based on experimental pressure
    e. Pressure based on experimental flow rate
    f. Flow rate based on experimental pressure

Sample Calculations

Experimental Flow rate

$$\frac{\text{volume (mL)}}{\text{time (s)}} = \frac{8.62}{180} = 0.0479$$

experimental pressure

$$\text{Pressure} = \rho g h$$

$$\text{pressure} = 9.97\times10^{8} \cdot 980 \cdot 25$$

$$= 244265000000.00$$

shear stress based on flow rate

$$\frac{Q \cdot 12 \cdot \mu \cdot L}{W H^3} = \Delta P \rightarrow \Delta P = \frac{.0479 \cdot 12 \cdot .01 \cdot 3.5}{(.035)(.035)^3}$$

$$\Delta P = 13,406.41$$

$$\tau = \frac{\frac{H}{2}\Delta P}{L} = \frac{\frac{.035}{2} \cdot 13,406.41}{3.5} = 67.03$$

Shear stress at the wall based on pressure

$$\tau = \frac{\frac{H}{2} \Delta P}{L}$$

$$\frac{\frac{.035}{2} \cdot 13406}{3.5} = 67.03 \text{ dynes/cm}^2$$

pressure based on experimental flow rate

$$\frac{Q \cdot 12 \cdot \mu \cdot L}{W H^3} = \Delta P \rightarrow \Delta P = \frac{.0479 \cdot 12 \cdot .01 \cdot 3.5}{(.035)(.035)^3}$$

$$\Delta P = 13,406.41$$

Flow rate

$$Q = \frac{W H^3 \Delta P}{12 \mu L} = \frac{.035 \cdot .035^3 \cdot 24500}{12 \cdot .01 \cdot 3.5}$$

$$Q = .0875$$

2. Insert a scatter plot of experimental flow rate vs. water column height below (Plot 1):

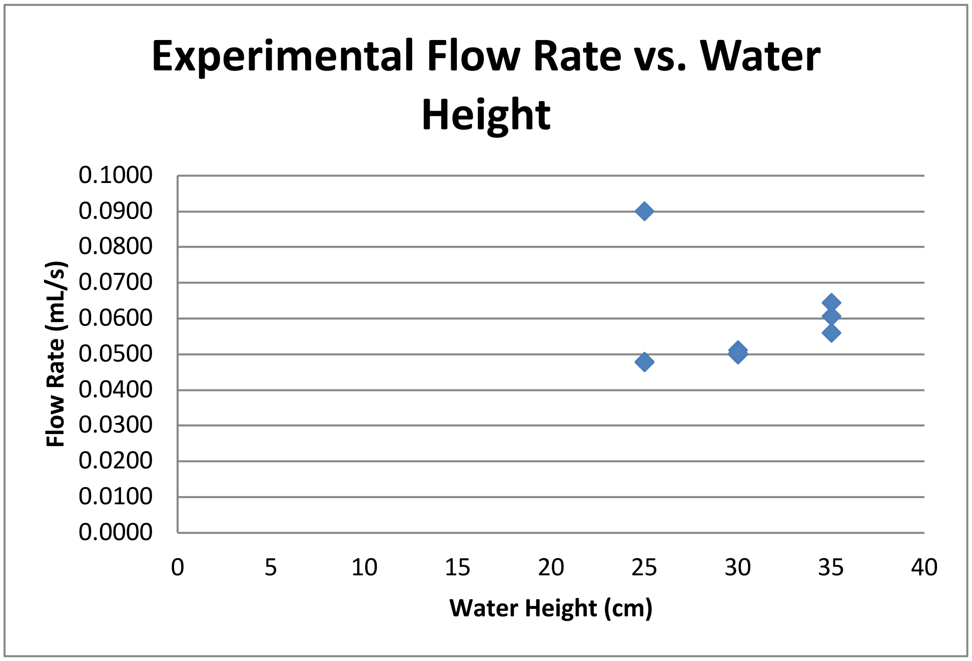


Figure 1: Experimental Flow Rate for each height measurement.

Briefly describe the relationship between experimental flow rate and water column height:

The relationship between the two variables is not strong, but shows a relatively weak, exponential relationship between water height and flow rate. This relationship is only evident after excluding the outlier data point at the top of the graph; if it were not omitted, there would be no clear relationship.

3. Insert a scatter plot of theoretical pressure (from your program using experimental flow rate) vs. water column height below (Plot 2):

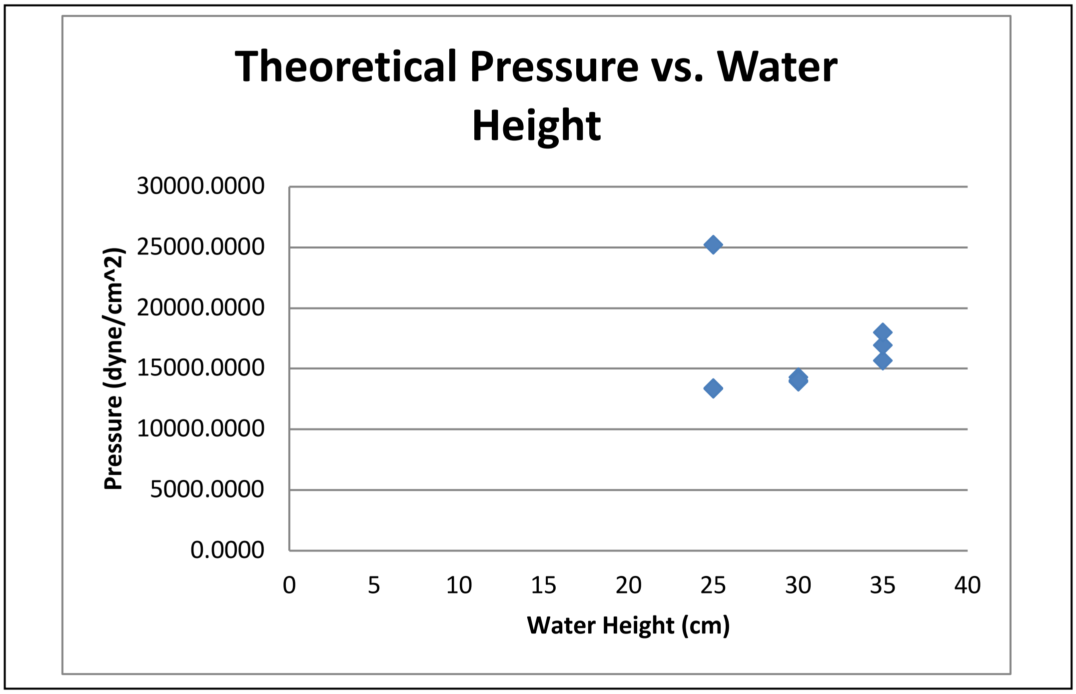


Figure 2: Calculated pressure valued for each measured height.

Briefly describe the relationship between theoretical pressure and water column height:

The relationship between the two variables is not strong, but shows a relatively weak, exponential relationship between water height and flow rate. This relationship is only evident after excluding the outlier data point at the top of the graph; if it were not omitted, there would be no clear relationship.

4. Insert a scatter plot with both experimental flow rate vs. experimental pressure and theoretical flow rate (from your program using experimental pressure) vs. experimental pressure below (Plot 3):

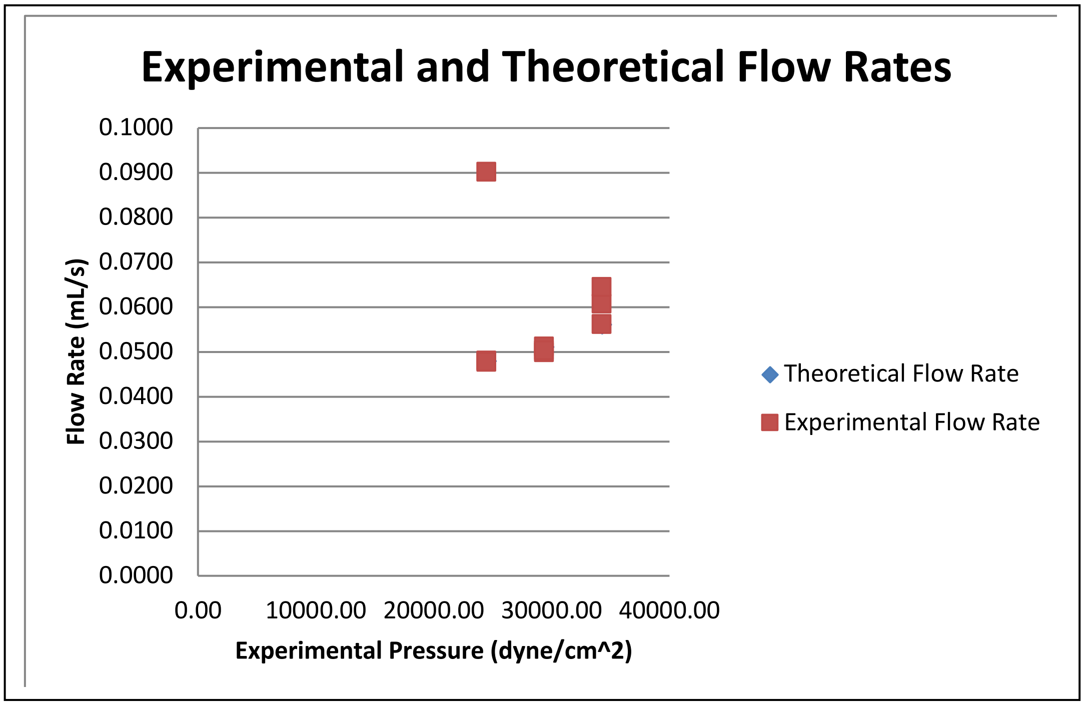


Figure 3: Theoretical and experimental flow rates for experimental pressures.

Discuss reasons why experimental flow rate differs from theoretical flow rate. Consider the following aspects of our testing:

- **Based on the assumptions of the fluid mechanics program, it should accurately describe the flow parameters of the standard chip.**
- **What assumptions were necessary to calculate the flow rate using your program? How good or bad are these assumptions when you consider the experiment?**
- **Were there any sources of error within the experiment that could account for differences in the theoretical and experimental flow rate?**
- **How could you improve upon either the experiment or program to address these differences? Is it feasible to adjust the assumptions of your program?**

In our experiments, we only had one outlier data point that showed an experimental flow rate completely different from the theoretical flow rate. Due to inconsistencies in our testing method, rising primarily from the change in pressure used to hold the water tubes in place, there was greater flow for one of the tests. The assumptions used to calculate our experimental flow rate did not lead to large systematic errors, so we did not find any inconsistencies with these assumptions and/or equations. The error that caused our outlier was, once again, most likely caused by issues in plugging the tubes into the chip. In the future, we could design the experiment such that the tubes are not removed and reinserted between tests. This would give the experiment more accuracy as it would involve a more consistent tube position across the different heights and would carry the water through the same channel geometry as before. If we keep removing the tubes and taking apart the chip after every experiment, we risk changing the geometry of the tube as we could tighten the chip too much or insert the chips too far before the next test (which would lead to a loss of flow).

Sensitivity Analysis:

5. Insert screen shots of your cut plots showing velocity contours below:

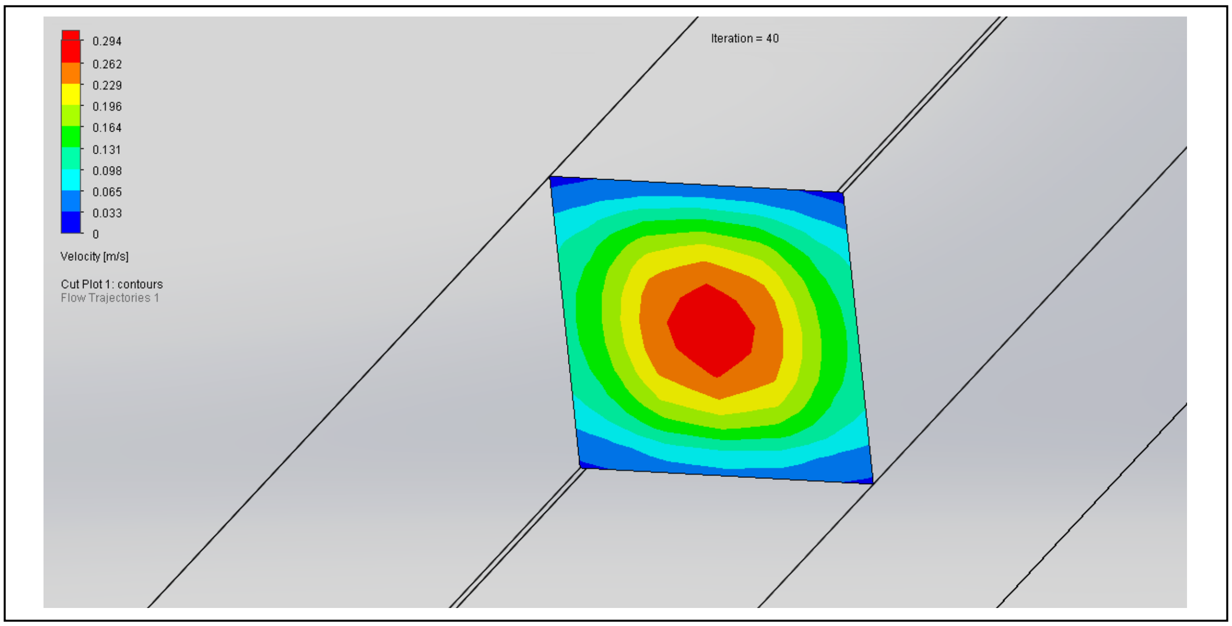


Figure 4: Velocity Cut Plot for Standard Height Channel

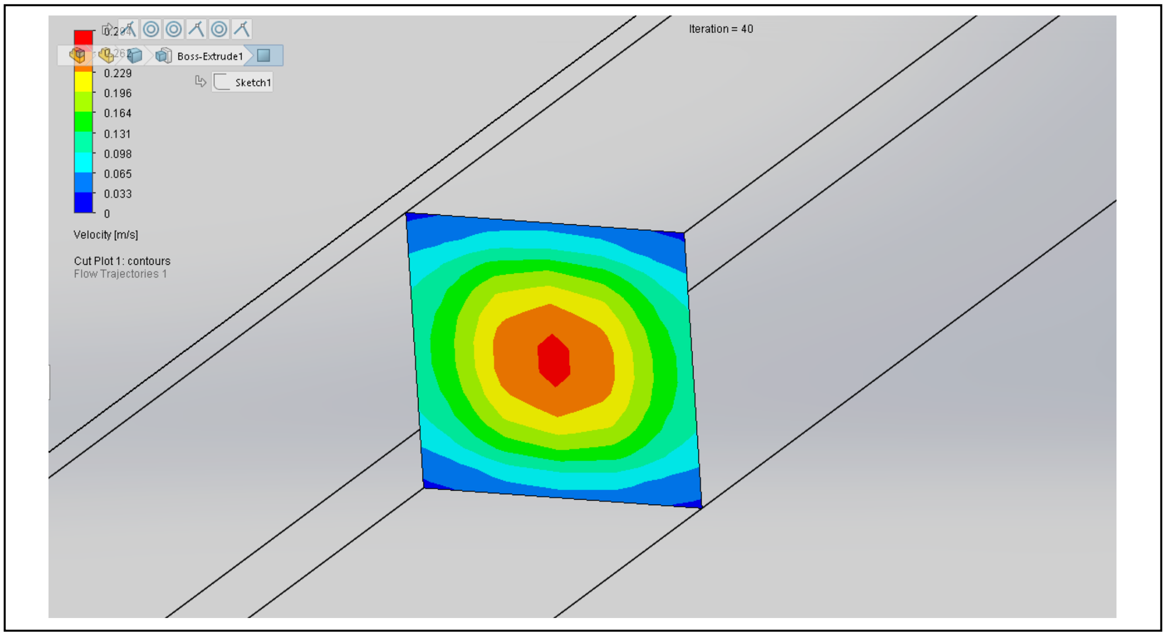


Figure 5: Velocity Cut Plot for Chip With 5% Smaller Height

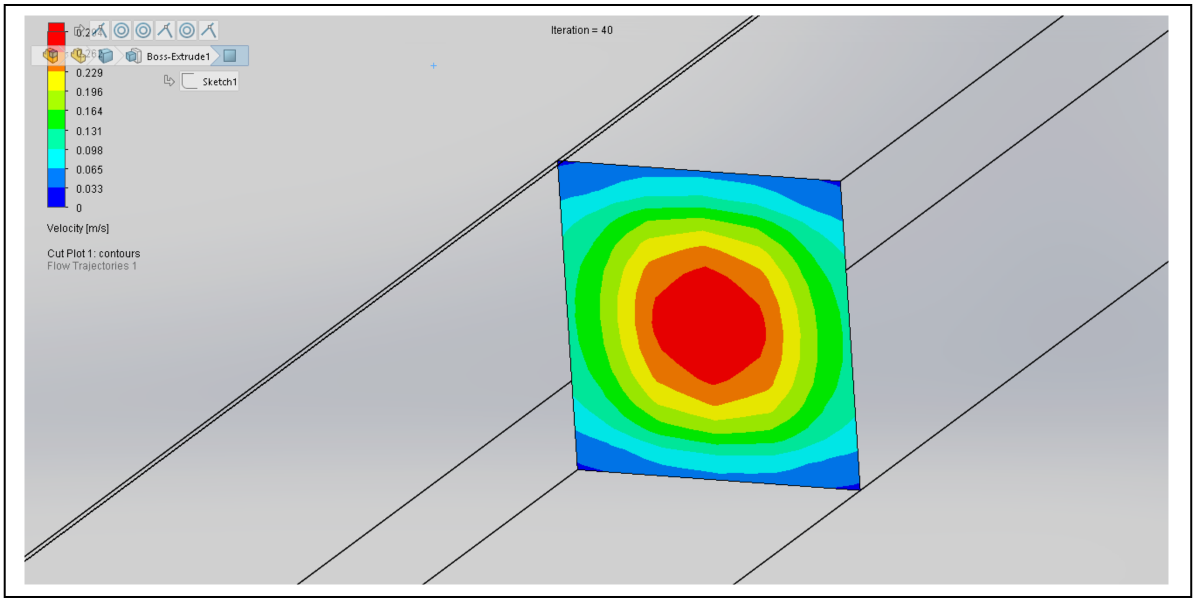


Figure 6: Velocity Cut Plot for Chip With 5% Larger Height

6. Insert a scatter plot of average and maximum velocity vs. channel height below:

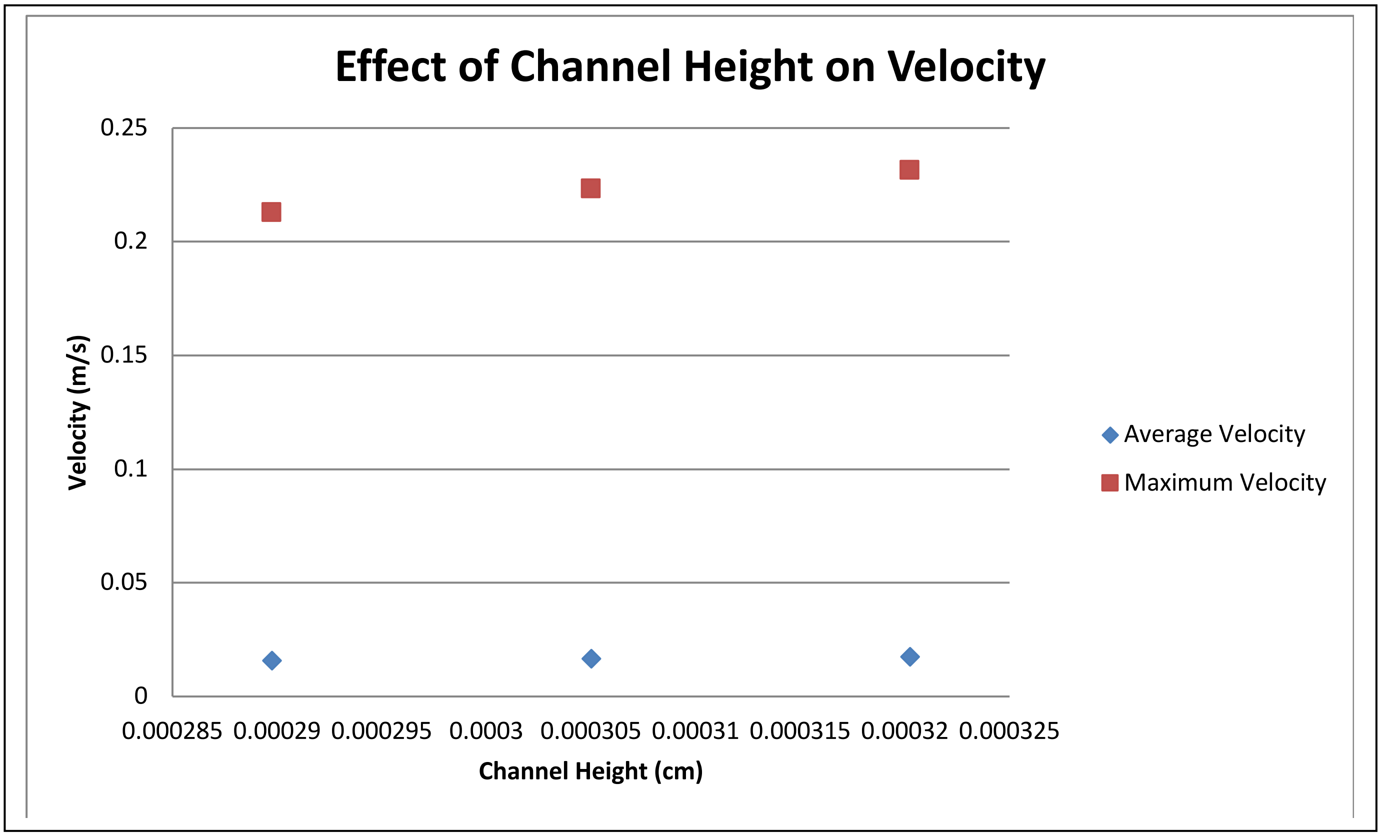


Figure 7: Scatter Plot of Channel Height Effect on Velocity

What trends do you see regarding the effect of channel height on velocity in the channel? Consider both the velocity contours and the channel velocities.

The most evident trend is an increase in velocity at almost every point in the velocity contour for the larger channels. Moreover, the larger channels had more circular contour shapes. The smaller channels not only had lower velocities (the red shades were not as dark and the colors of the contours were closer to the lower velocity values), but they also had more oblong-shaped contours.

7. Insert screen shots of your surface plots showing shear stress profile below:

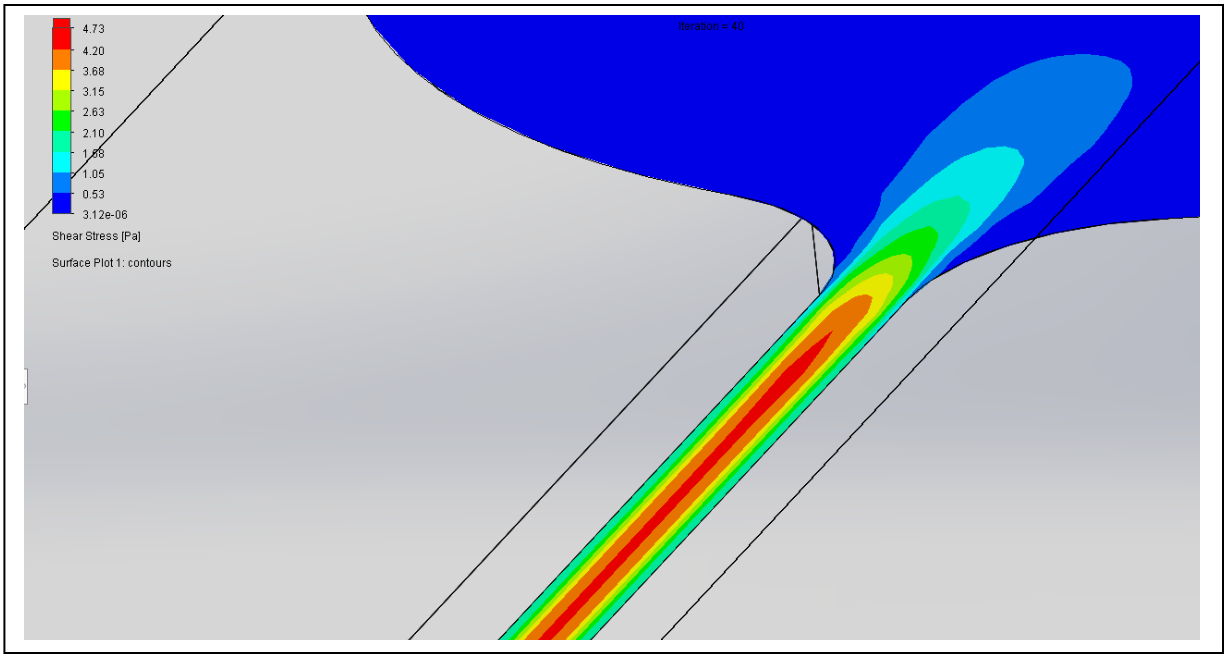


Figure 8: Shear Stress Surface Plot of Standard Chip

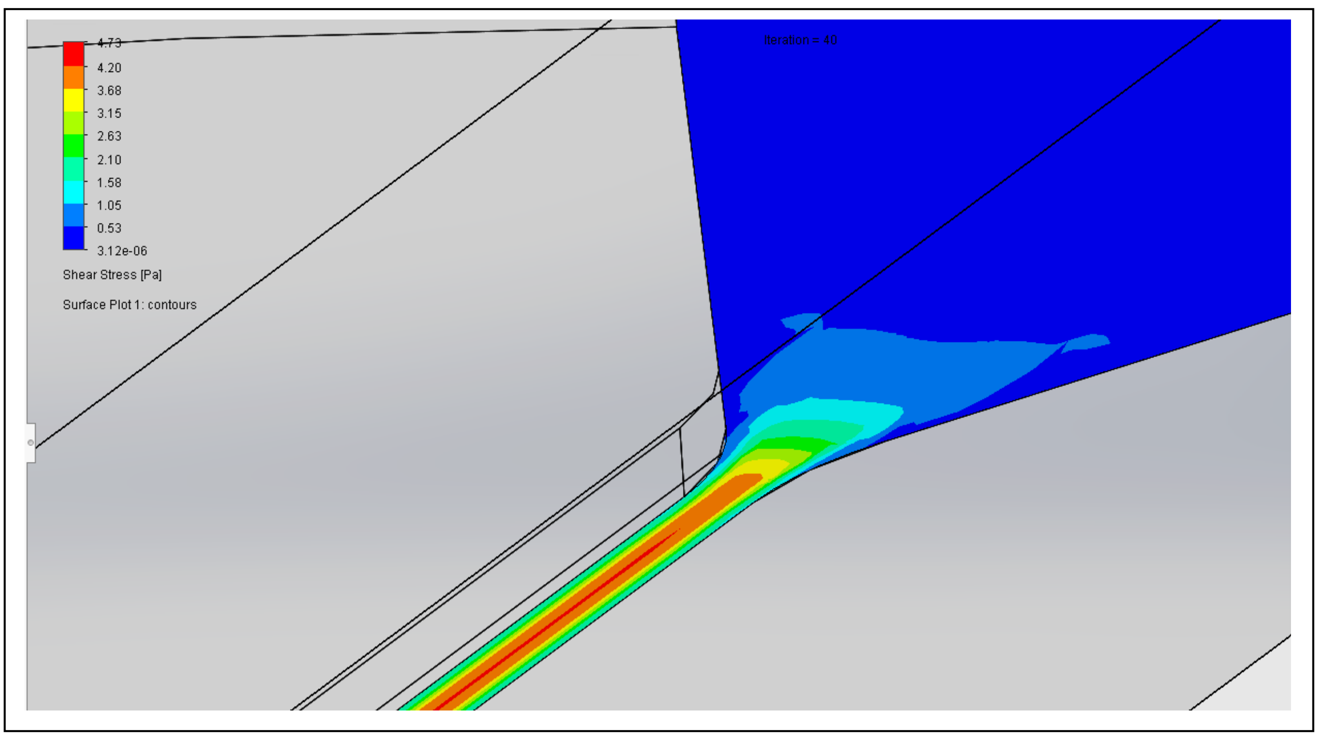


Figure 9: Shear Stress Plot of Chip With 5% Smaller Height

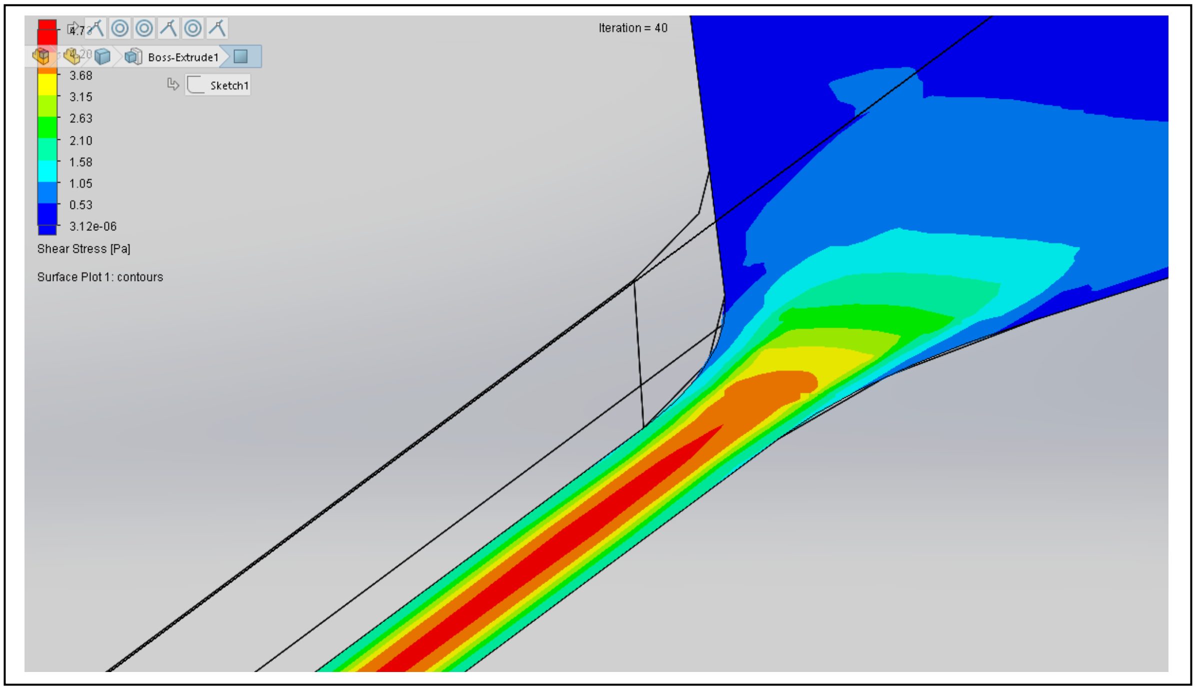


Figure 10: Shear Stress Plot of Chip with 5% Larger Height

8. Insert a scatter plot of average and maximum shear stress vs. channel height below:

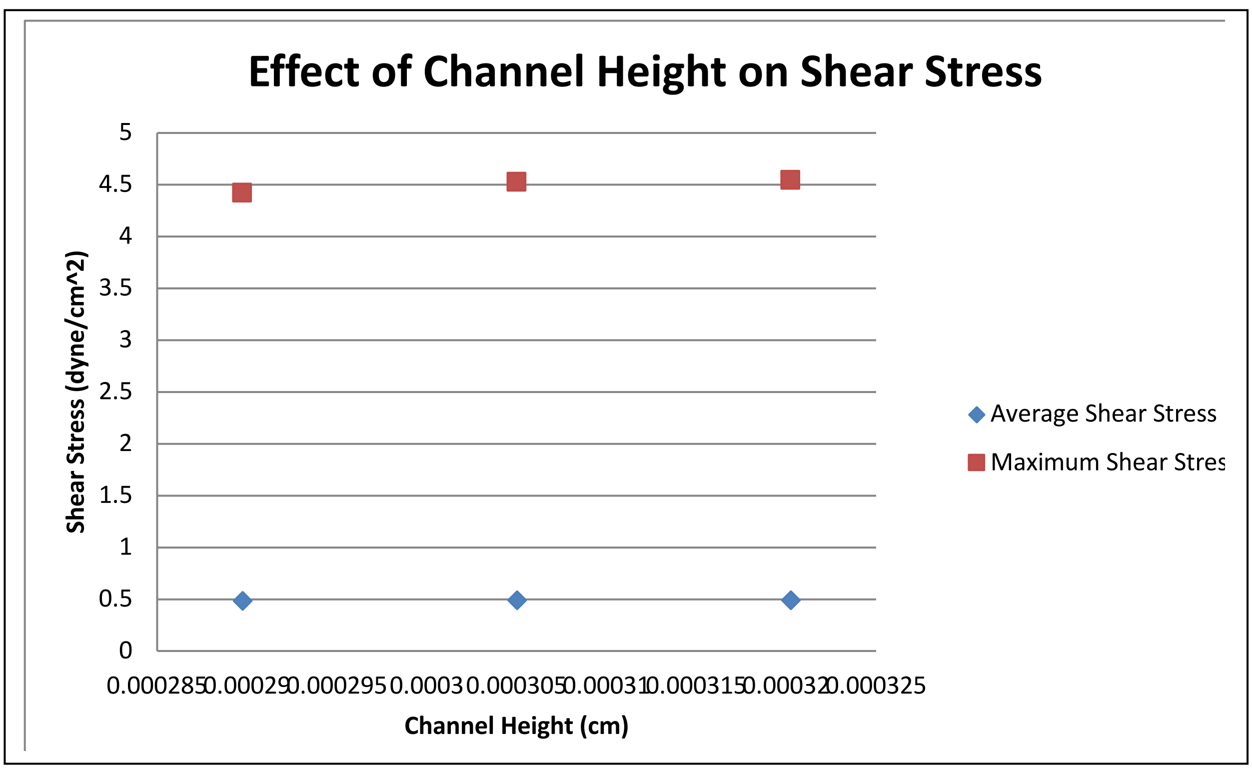


Figure 11: Scatter Plot of Effect of Channel Height on Shear Stress

What trends do you see regarding the effect of channel height on shear stress in the channel? Consider both the shear surface plots and the channel shear stress values.

The channel height did not cause much of a change in average shear stress, however the max shear stress does increase as the channel height increases. Also, according to the surface plots the area in which the max shear stress is smaller as the chip gets smaller.

9. **Will the results of your sensitivity analysis affect your chip design or experimental procedure? Why or why not? If so, how will it affect your design? Use quantitative data to justify your decision.**
   I do not see the results of the sensitivity analysis having a large impact on the design or experimental procedure, as the shear stress and velocity values at different heights were similar. Especially since we are not exactly sure what optimal velocity and shear stress are, it would be inefficient to try to optimize these based on chip channel height when they can more effectively be altered and optimized through changing the pressure difference.

10. Below is a screen shot of a shear stress surface plot:

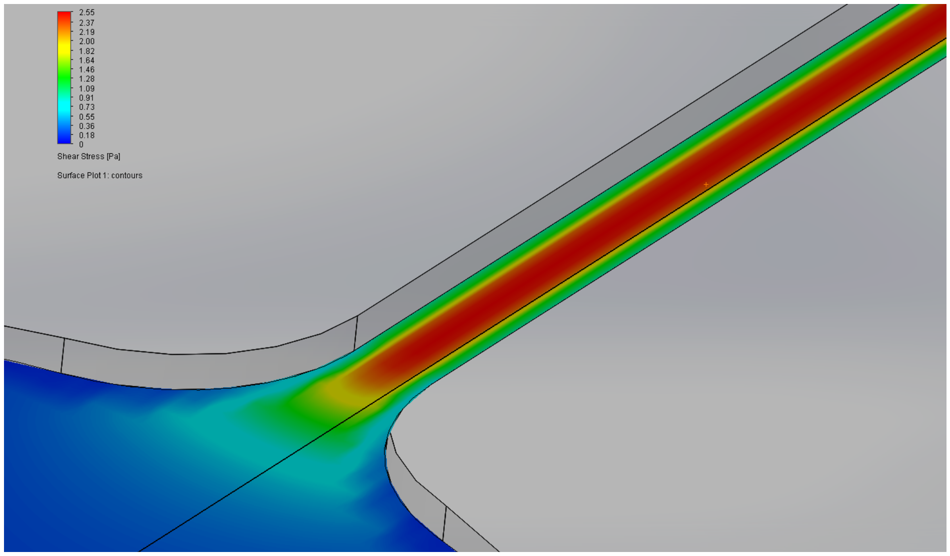


Figure 12: Shear stress surface plot.

Based on the assumptions of our fluid mechanics worksheets, the bottom of the channel should have a uniform shear stress across the width of the channel. It is apparent from this surface plot that this is not the case. Using the assumptions present in our shear stress derivation and in the solid works flow simulation, explain why the shear stress is not uniform across the channel. (Hint: What did we assume regarding the x-dimension of our channel?)

The shear stress is not the same across the width of the channel. The x-direction of the channel is different than it was in our assumptions as this channel has walls and is not infinitely long. Because of the presence of walls in the channel, water molecules are forced to interact and push on each other, and the shear stress is not uniform across the floor.

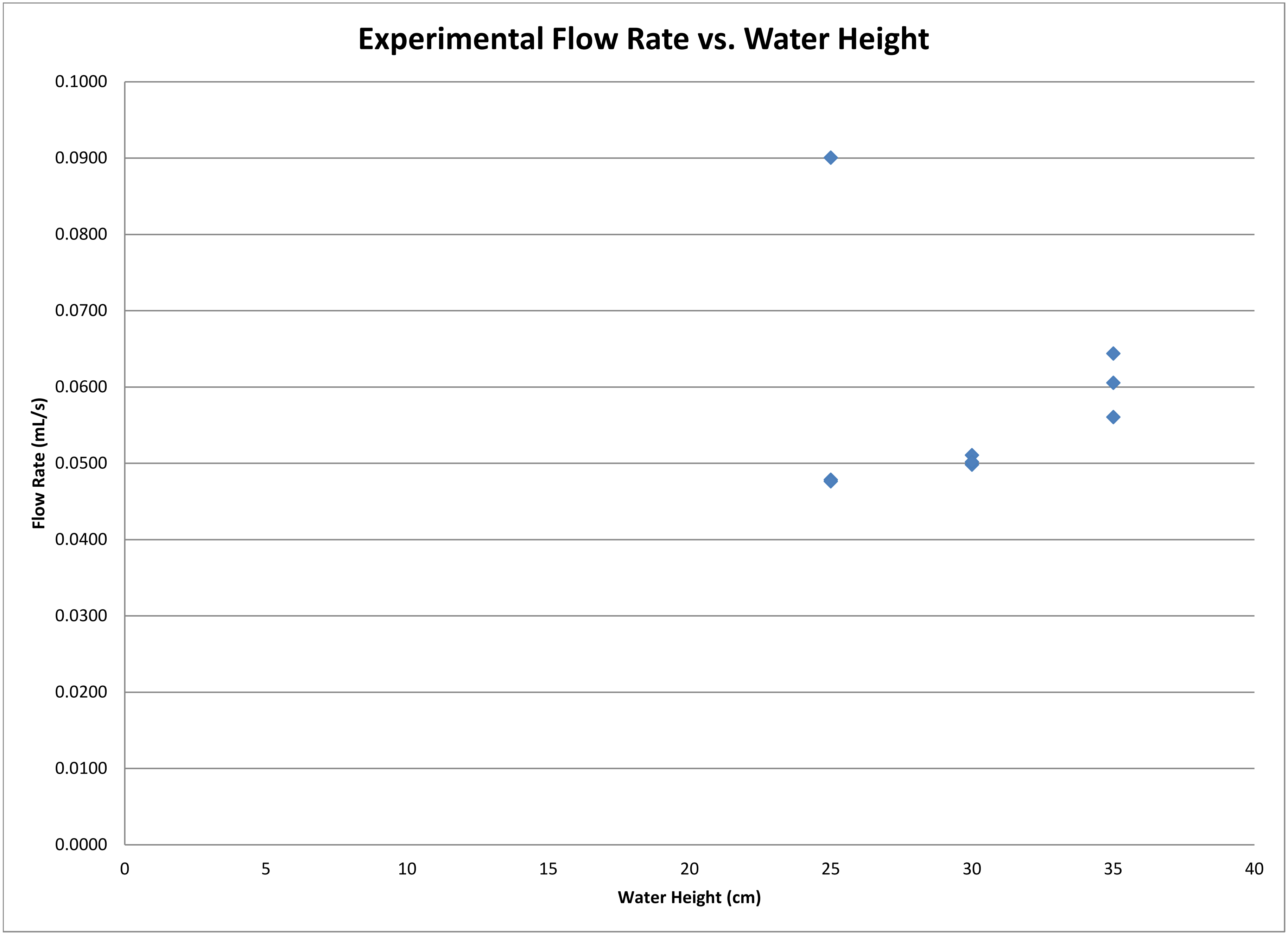
ENGR 1282.02H - FEH Nanotechnology

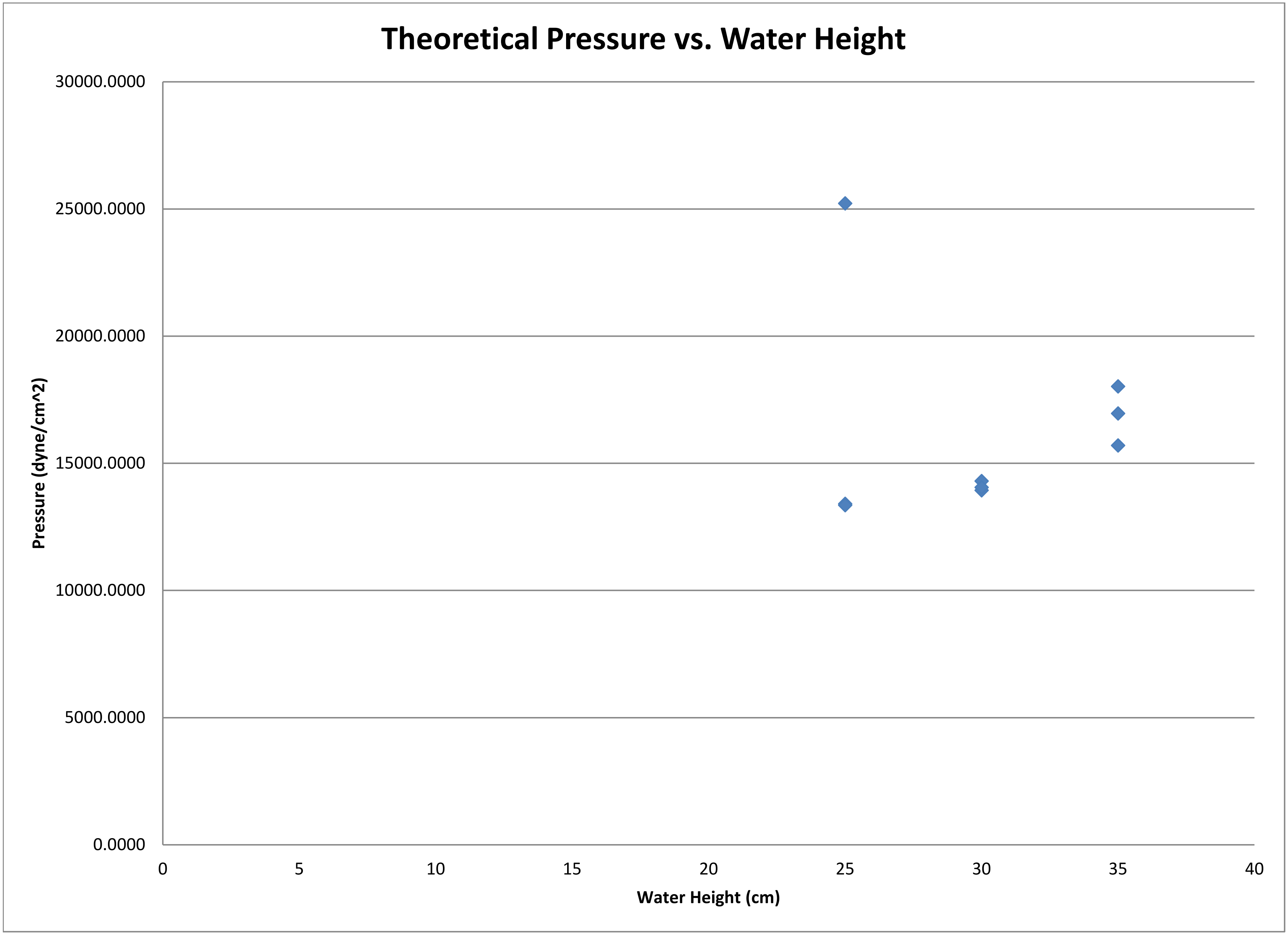
Microfluidics Flow Calibration Datasheet

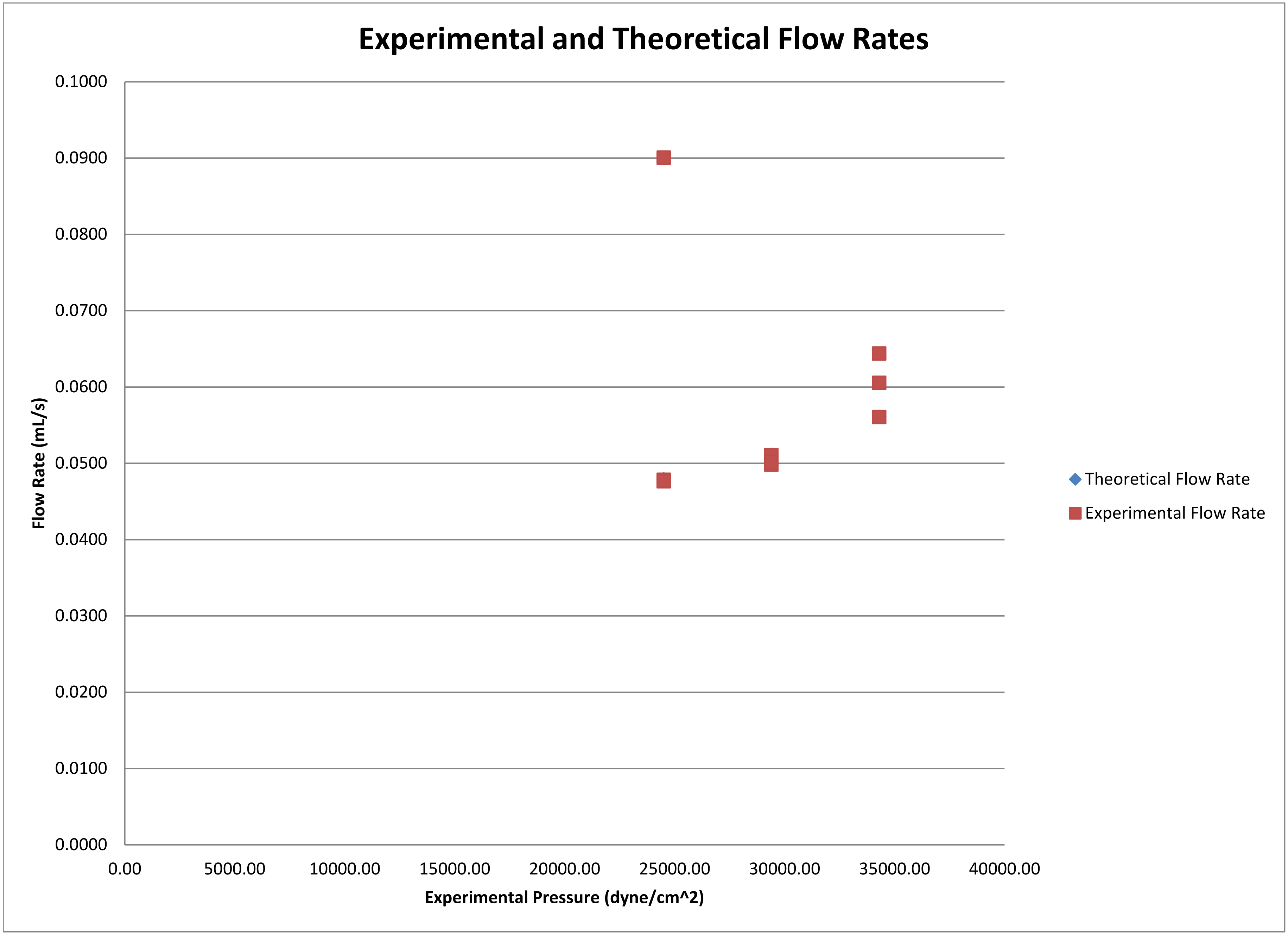
Team Name: y4 **Professor / Class Time:** Parke 12:40

Raw Experimental Data				Calculated Directly from Experiment			Calculated from your program using experimental flowrate and NOT pressure as inputs				Calculated from your program using experimental pressure and NOT flowrate as inputs				
Height (cm.)	Trial	Volume (mL)	Time (s)	Experimental Q (mL/s)	Experimental Pressure (dyne/cm^2)	Experimental Q Mean (mL/s)	Pressure (dyne/cm^2)	V_{avg} (cm/s)	Reynolds Number	Shear Stress at Wall (dyne/cm^2)	V_{avg} (cm/s)	Reynolds Number	Shear Stress at Wall (dyne/cm^2)	Theoretical Q (mL/s)	Max Shear Stress
25	1	8.62	180.00	0.0479	24500.00		13406.0000	39.1020	136.5150	67.0371					126.0950
25	2	8.58	180.00	0.0477	24500.00	0.0619	13350.0000	38.9388	135.9450	66.7500	50.8636	136.5108	86.6274	0.0479	
25	3	16.21	180.00	0.0901	24500.00		25217.0000	74.5500	256.7850	126.0950					
30	1	6.13	120.00	0.0511	29400.00		14302.0000	41.7143	145.6350	71.5100					71.5100
30	2	5.98	120.00	0.0498	29400.00	0.0504	13938.0000	40.6531	141.9300	69.6900	41.1158	145.6346	70.4833	0.0511	
30	3	6.02	120.00	0.0502	29400.00		14050.0000	40.9800	143.0700	70.2500					
35	1	3.36	60.00	0.0561	34300.00		15701.0000	45.8000	159.8900	78.5100					90.1200
35	2	3.63	60.00	0.0606	34300.00	0.0603	16961.0000	49.4700	172.7100	84.8000	49.2800	159.8803	84.4767	0.0561	
35	3	3.86	60.00	0.0644	34300.00		18024.0000	52.5700	183.5400	90.1200					

Fluid Density (g/ml)	1.00
channel height (μm)	35000.00
channel width (μm)	35000.00
channel length (μm)	3500000.00
Fluid Viscosity (g/cm-s)	0.01


Experimental Flow Rate vs. Water Height
Flow Rate (mL/s)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0
5
10
15
20
25
30
35
40
Water Height (cm)


Theoretical Pressure vs. Water Height
30000.0000
25000.0000
20000.0000
15000.0000
10000.0000
5000.0000
0.0000
Pressure (dyne/cm^2)
0
5
10
15
20
25
30
35
40
Water Height (cm)



Experimental and Theoretical Flow Rates
Flow Rate (mL/s)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0.00
5000.00
10000.00
15000.00
20000.00
25000.00
30000.00
35000.00
40000.00
Experimental Pressure (dyne/cm^2)
Theoretical Flow Rate
Experimental Flow Rate

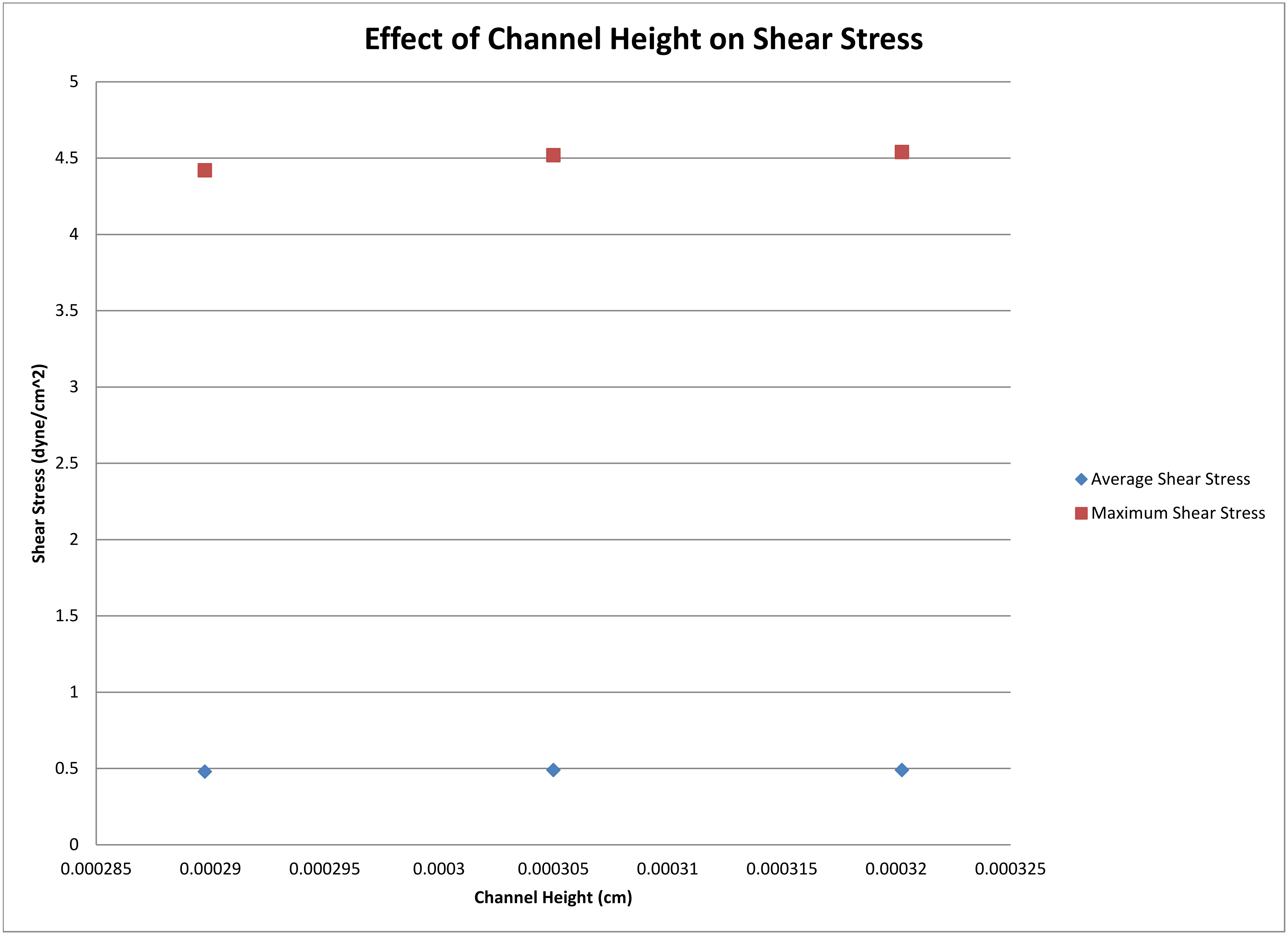
ENGR 1282.02H - FEH Nanotechnology

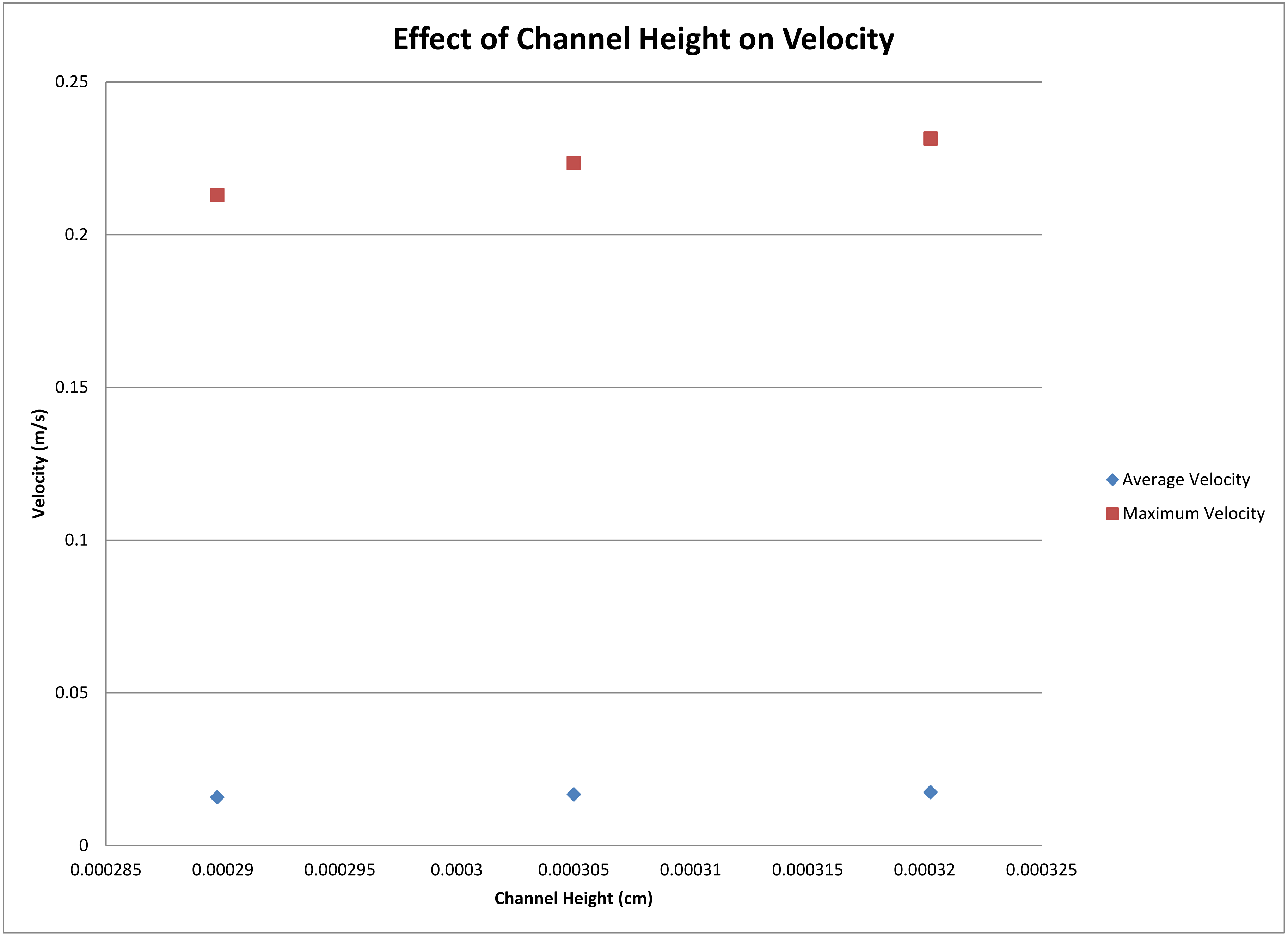
LOC Sensitivity Analysis

Team Name: Y4 **Professor / Class Time:** PArke 12:40

Channel Height (cm)	Average Shear Stress (dyne/cm^2)	Maximum Shear Stress (dyne/cm^2)	Average Velocity (m/s)	Maximum Velocity (m/s)
0.00032025	0.49	4.54	0.017526	0.23152
0.000305	0.49	4.52	0.0168159	0.223441
0.00028975	0.48	4.42	0.0158358	0.212968

39.1008
41.7142
45.7946


Effect of Channel Height on Shear Stress
Shear Stress (dyne/cm^2)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.000285
0.00029
0.000295
0.0003
0.000305
0.00031
0.000315
0.00032
0.000325
Channel Height (cm)
Average Shear Stress
Maximum Shear Stress



Effect of Channel Height on Velocity
0.25
0.2
0.15
0.1
0.05
0
Velocity (m/s)
0.000285
0.00029
0.000295
0.0003
0.000305
0.00031
0.000315
0.00032
0.000325
Channel Height (cm)
Average Velocity
Maximum Velocity