

Penn State RET in Interdisciplinary Materials
Unit Plan - Teacher's Preparatory Guide
Matthew Graham

Microfluidics

Purpose:

This lab provides students with a hands-on activity that can be used to teach and better understand fluid dynamics. Another purpose is to educate students and expose them to real life applications of these principles in a new and upcoming field, which is microfluidics.

Objectives:

This 3-day lab is designed to help students:

- Understand how fluids flow.
- How can microfluidic chips achieve Laminar flow?
- Can we construct a microfluidic chip?
- Can we measure flow rate?
- Can we observe diffusion between two solutions?

Time required: 75-minute Lab period to build can construct the microfluidic chip, two 48-minute class to gather data via testing and to calculate variables.

Level: High school

- **National Science Education Standards**
- **PS2.A:** Forces and Motion: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- **HS-PS2-6:** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.
- **HS-LS1-2 From Molecules to Organisms: Structures and Processes**
- Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- **HS-LS1-2 From Molecules to Organisms: Structures and Processes**
- Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

Teacher Background:

Background info that will be needed will be as follows:

- Understanding of how liquids flow
- Being able to use Bernoulli's Principle
- Being able to explain Laminar flow
- Knowing and understanding the flow rate equation
- Knowing what Poiseuille's law is.
- What is a Coacervate?
- Understanding how microfluidics work.
- How are microfluidics used in science today

Materials

- Water
- Food color
- Microscope
- Parafilm
- Scissors
- Cricut*
- Plexiglass (1mm) [Amazon PET Plexiglass](#)
- A heating source (Ex: oven at 50 degree Celsius)
- Weight to help seal chip during curing phase
- Drill
- Drill bits
- Appropriate drilling surface (Ex: scrap wood)
- Microfluidic tubing [Microfluidic Tubing](#)
- Pipet Tips
- Syringes (1 or 10ml)
- Epoxy [2-Part Epoxy](#)
- Toothpick and scrap paper to mix Epoxy
- Test tubes to hold water
- Test tubes to hold coacervates
- Test tubes to hold Salt solution
- Area to store microchips to cure

Chemicals including PDADMAC (8.5 kDa and 100Da), PAA (1.5 kDa and 130kDa), and salt (NaCl)

Advance Preparation:

- Purchase the plexiglass ahead of time, you will need to gather all the materials ahead of time.
- Premix the different solutions the day before the lab/testing/data collecting day.
- Prefabricate have a few different channels cut out either by hand or using a Cricut if you have one on the parafilm. The single channel is great for measuring flow rate, where the x or y shape is great for observing laminar flow and diffusion.
- Precut the plexiglass before to not be wasteful.
- Cricut should be set up and linked to Bluetooth on laptop if available.

Safety Information:

No additional safety precaution than usual procedure, wear safety glasses. Using cutting gloves when cutting.

Teaching Strategies:

I would consider having each student find a singular partner to work through this lab. I plan to show them some of the tests that I did, and the steps I took to create the chip and test it. When it comes to teaching strategies, I suggest we allow them to be explorative and learn using problem-solving skills when creating a chip. When it comes to calculations, more help is needed, but showing them my work and what some acceptable results are will be a good guide to allow them to be successful. They will be given directions; it should be a very explorative lab. For time purpose, when constructing the chips, they should build both chips simultaneously.

Resources:

I would consider using this scientific paper found during my time at the Keating lab as a resource to refer to when explaining what microfluidic is, how does it work, and why does it matter.

<https://pubs.rsc.org/en/content/articlelanding/2016/ra/c6ra18988a>

<https://en.wikipedia.org/wiki/Coacervate>

<https://en.wikipedia.org/wiki/PolyDADMAC>

https://en.wikipedia.org/wiki/Polyacrylic_acid

Overview for the activities:

For a 75-minute lab class:

- (15-minutes) Show the class my poster of what I did this summer, what I tested, what were my goals, how I achieved them, how I need to make changes, where I made mistakes, what were the steps I took.
- (10-minutes) To present them with the task at hand, the material needed, the goals and steps I took to build a chip. They are required to build two different chips, one is y or x shaped that falls into the guidelines from when I did the lab these should be prefabricated by the teacher or by using a Cricut, similar to the one I will show them, the other is a single channel to be used for measuring flow rate.
- (45-minutes) They must design, cut, prepare opening in plexiglass and produce two chips that are ready to be sealed and tested the next class period to measure flow, and use Poiseuille's law to find each solution viscosity

- (5-minutes) clean up.

For two 48-minute class:

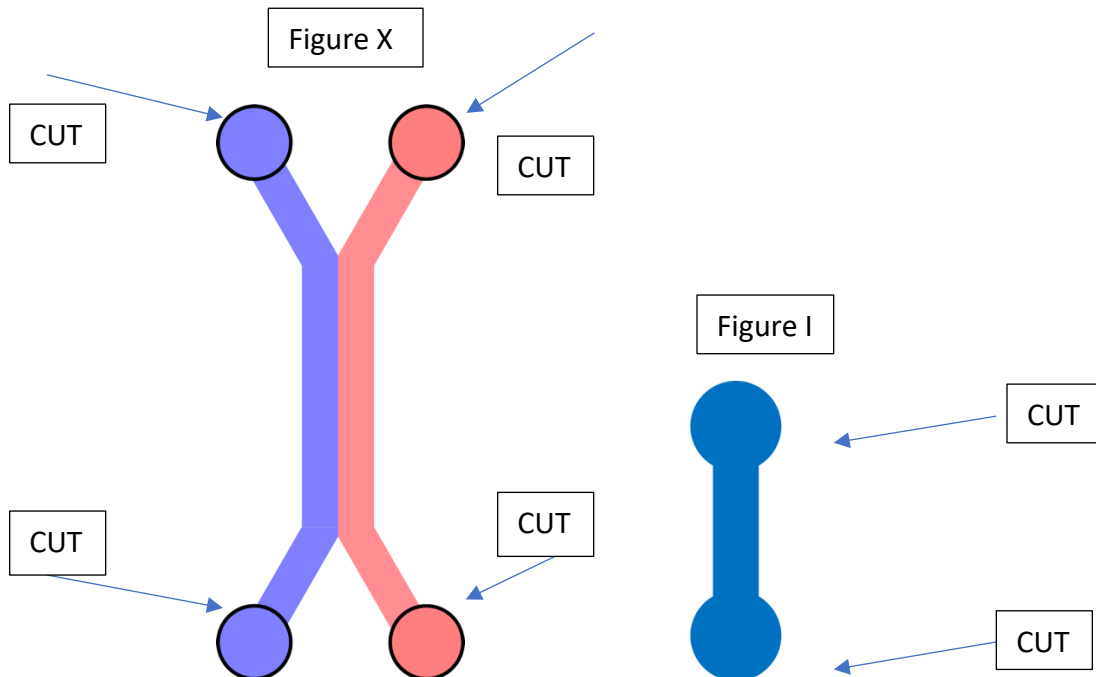
- Students will find there two different chips that I had cured and are now ready for testing.
- (43 minutes) They will next need to adhere the pipet tip to the chip, over the hold they drilled in the top layer of the plexiglass to allow the fluid to flow in. Make sure it is staying in place, we don't want any epoxy in the channel. Using epoxy, make sure students are on task. Let that set for at least 5-10 minutes, the longer the better. While that is drying have them do some sample calculations using Poiseuille's law to make sure they can find viscosity in sample problems. Address any errors if needed.
- Students will get their chips and construct the apparatus of the syringe, and tubing that attaches to the pipet tips that are now attached to the chip and have a container to catch the waste material, and vial with each solution that will be added to the chip. Each student will add a certain volume of each solution, measure the time it takes to flow through the channel, measure the channel length, and measure the radius of the channel they created. Using a syringe or pipets would help reduce the chance of spilling solutions.
- Each chip will need to be cleaned before testing the next solution or a reaction will occur. To do so, at least 10 ml of NaCl need to pass through the chip, and followed by at least 10 ml of water, preferably dionized if you have it.
- From there they will calculate asked values, determine from calculation what is the solution they given as it is unknown to them. Calculate a percentage error, and graph their findings.
- (5 minutes) Have them clean up after the single flow chip. They will need to clean the chip with NaCl and water. For homework have them make sure that their data tables are completed.
- Next day(43 minutes) Repeat the same steps with their own design, being the x. Have them mix two different solutions together using the device and have them explain what is happening.
- Finally try this with the PAA and PDADMA in either the x chip. Have them record what they see. Have them take the chip to a microscope and see what they are looking at. See if they can see a membrane form, or not.
- (5 minutes) Clean up and return material to where you found them.

Procedure:

Locate all materials provided by the teacher.

Follow the directions on the page in the lab provided. Read the directions before attempting to make your chip. Understanding what is going on will be vital to your success in building a microfluidic chip.

1. First is to design the parafilm channel. To do that you will need to use a Cricut if you have access to one, if not you will need to do this by hand with a sharp instrument.
 - a. The channel either shaped or a straight line needs the inlet and exit areas to be a little bigger than the channel to see the best results.
 - b. Take a 6 x 4 piece of parafilm and lay that out on the table, on the paper side draw the channel you want. It has to be the single channel and then the x channel, like the shapes below. One chip per shape. Once you have drawn that, shade in the inside of the shape. That is the part that needs to be removed. NOTE: You cannot cut to the shaded area, it must stay one solid piece of the chip won't work. You may have to use an exact-o knife or scissors to remove the shaded area without ruining the channel.
 - c. Once you have created the parafilm channel you are ready to move to the next part. If you have access to a Cricut, you will see better results. Cutting directions for that can be found at extension 1.



2. Take a plexiglass precut slide and make sure the plexiglass is free of any debris.
 - a. Place the cut out parafilm on the plexiglass. With a sharpie mark on the plexiglass where the inlet and outlet holes should be. Mark these on what will be the top of the chip, and mark where you will not hit the parafilm when you drill. We want the fluid to only go into the channel so center of the circle is idea for the access hole.
 - b. Once you have your hole marked, remove the parafilm you will need a 1/8-inch drill bit to cut the hole. On a designated work area, place the plexiglass on the work

area and use the drill and drill bit to make the inlet and exit holes.

- c. Once the holes are drilled, clear any debris from the slide as we are about to add the parafilm cut out provided. (X-shaped) You will need to make sure that the parafilm cut up lines up accordingly with the holes drilled in the slide. The top holes in the parafilm need to be lined up with the slide. The slide with the holes is going to be the top of the chip when we are completed. Once the parafilm is placed on the chip, trimmed of any excess parafilm that is laying outside of the slide, make sure you press the parafilm down onto the slide with some force to make sure it will not slide for the next step.
 - d. We will be adding the bottom layer of plexiglass to the chip, here we will need to make sure it is centered accordingly. Once centered accordingly, apply pressure to keep the slide in place, too much pressure leads to broken plexiglass so be careful.
3. Once the slide has been created, we will be applying pressure in the form of applied weight, and some heat to allow for the parafilm to cure the plexiglass to create an airtight seal. Bring your chip to your teacher and they will show you how to do this, make sure it is labeled as the student's chip.
 4. Extension 1: DESIGN YOUR CHIP
 - a. You will be designing your own chip, you can use a variety of different ideas, shapes, or patterns to see if you get the same results. The only stipulation is the fluid in channel a must travel the same distance as channel. Different displacements lead to different mixing rates. The design, also has to be a single channel.
 - b. To design your parafilm cut out you will be using a machine called a Cricut, this is a device that is used for cutting in detail. To design your cut up you will be using the Cricut app that you can download from their website.

<https://design.cricut.com/#/>

- c. In this design space you need to use lines, circles, or different shapes to create a channel for a fluid to flow. They have a grid that will help you when creating these designs. Once you have your design, you must use the function weld the part together, if there are gaps in the design, the machine will not cut as you envision.
- d. Note that parafilm is only 4 inches wide, so your channel needs to fit inside that area. Recommended width would be at most 3.5 inches and centered in between 0 – 4 inches.

- e. Once the design is finished find your teacher and they will walk you through the cutting process. Make sure you save your project, as the printer is 90% effective. Tearing can occur if the channels are too small.
 - f. Once your new channel is created, repeat steps 1-4 for the new channel.
5. Cleanup for day one:
- a. Have Students collect all materials and put them back where they found them, have them return sharp instruments to the teacher, have them dispose of scrap material that is not reusable. Have them put the chip they have created in a place that will not damage like a window ceil, preferably on a tray so you can transport them easily to the oven to allow them to cure. Make sure that students are careful of their classmate's projects.
 - b. After class, the teacher will put the chips in an oven that is about 50-degree Celsius for about an hour which has a weight sits on top of the chip to make sure the chip seals while curing.
 - c. Once the chip has cured for an hour, make sure the chip is then placed in a refrigerator to chill for an hour after. After they have chilled, they should look semi translucent. You should not be able to see air bubbles in the chip either. After this is done, the chips can be taken back to class the next day.
6. Day Two Continued:
- a. Students will be given their cured chips that the teacher would have cured for the students the night before.
 - b. Student will be given 3 or 4 pipet tips, depending on their design that is corresponding to the number of inlets and outlets the chip has.
 - c. Student will then need to adhere the pipets to the chips. They will be using 2-part epoxy. They will need to mix equal parts of the hardener and adhesive. Using a toothpick, make sure they are using multi-layered paper or cardboard to mix the epoxy on. Make sure the students are on task as they can be a hazardous step. Make sure students have latex gloves on when they use the 2-part epoxy.
 - d. With the mixed epoxy, students will sit the pipet flush to the chip over the hole drilled in the top layer, and students will adhere the tip to the chips top layer. Students need to make sure the tip is well secured, is sitting at a 90-degree angle, and it is pivotal that no epoxy gets into the chip's inlet hole.
 - e. The epoxy takes 5 minutes or so to set, using clamps or any other type of instrument to hold the pipet in place would be ideal for best result and only doing focusing on one pipet at a time, but not necessarily.
 - f. Students would have to adhere all the pipet tips to the chips; if you did multiple chips, this would take them a while.
 - g. Make sure students are not wasteful with the epoxy and they dispose of surface used to mix epoxy.

- h. Have student turn in the chips to allow them to set over night. Make sure they clean up accordingly.
7. Day Three Continued:
- a. Hand back the chips to the students and give them the following materials.
 - i. 3-4 syringes depending on their design.
 - ii. Precut 3-4 six-inch pieces of micro fluidic tubing
 - iii. The four different solutions.
 - 1. I used the following, but you can use whatever you want if you are just trying to do multi-channel on your own. You could use olive oil, water, rubbing alcohol, milk or anything you can think of if you don't want to deal with or have these chemicals. If you want to create a membrane in the chip, you need something that creates a precipitate like these listed.
 - a. PAA 1.8 K
 - b. PAA 130 K (diluted 1:50)
 - c. PDADMA 8.5K
 - d. PDADMA 108K
 - iv. A ring stand.
 - v. Two clamps to hold the syringes that holds the fluid that flows into the chip through the tubing.
 - vi. A waste container to catch the material that flows out of the chip through the piping.
 - vii. A microscope if you want them to see a membrane formed if you choose to do that part of the lab
 - b. Have students read the directions in the application part of the lab.
 - c. Have them record measurements and record them in the tables from the lab.
 - d. Each chip will need to be cleaned before testing the next solution or a reaction will occur. To do so, at least 10 ml of NaCl need to pass through the chip, and followed by at least 10 ml of water, preferably deionized if you have it
 - e. Have them run the trials at least 2 times if time allows, it not make a class table via google sheets where students can enter in data they collected.

Solution making steps: From Steve Shultz Keating Lab

THIS NEEDS TO BE DONE BY THE TEACHER AND DONE AT LEAST A DAY BEFORE IT IS NEEDED FOR THE LAB.

8. To prepare PDADMAC, we will be diluting molecular weight <100K, 35% wt polymer solution to 9.4% with water and using NaOH for pH buffering.
 - a. Dilute 8.0 mL of 35% wt solution with 150 mL deionized water. Stir and vortex mix if needed.
 - b. Test the pH with pH paper. The pH needs to be as close to 7 as possible to achieve that add one drop at a time 0.1 M NaOH and retesting the pH after stirring in each drop.
 - c. Add water to reach a total volume of 200. mL. Stir and check the final pH.
 - d. Repeat a-c with PDADMAC, solution prepared by diluting molecular weight 8.5k, 35% wt polymer solutions to 9.4% with water and NaOH for pH buffering.
9. PAA, solution prepared by diluting molecular weight 1.8K solid polymer in water and NaOH for pH buffering.
 - a. Dissolve 1.35 g PAA in 150 mL of the deionized water. Stir and vortex mix if needed.
 - b. Test the pH with pH paper. The pH needs to be as close to 7 as possible to achieve that add one drop at a time 0.1 M NaOH and retesting the pH after stirring in each drop. PAA will take more NaOH to get the solution to balance to a pH of 7.
 - c. Add water to reach a total volume of 200. mL. Stir and check the final pH.
 - d. Repeat a-d with PAA, solution prepared by diluting molecular weight 1.8K solid polymer in water and NaOH for pH buffering.
10. 1.5M sodium chloride solution prepared by dissolving 99% pure NaCl in water and NaOH for pH buffering.
 - a. Dissolve 13.9 g NaCl in 150 mL deionized water. Stir and vortex if needed.
 - b. Test the pH with pH paper. The pH needs to be as close to 7 as possible to achieve that add one drop at a time 0.1 M NaOH and retesting the pH after stirring in each drop
 - c. Add water to reach a total volume of 160.0 mL.

Application

11. Measuring each fluid:
 - a. Each student will add a volume of solution to the channel via the syringe, record the time it takes to flow down the channel and exit the chip. **We will use gravity as the force that allows the fluid to flow.** To get the flow started, the chip will need to be primed. To do that we will use a syringe and a tip, attach it to the tube/tubes and create a partial vacuum to get the fluid to start to flow. The student will then use the fluid flow equations to find the

viscosity that the fluid is flowing and compare their finding to an expected value.

b. To get started, students will add 3ml of each solution to the syringe, the students will then prime the chip and allow it to start to flow through the chip and out the tubing into the waste container.

c. Students will start timing the amount of time it takes for each solution to flow from 2 ml to 1ml and 1ml to 0ml.

d. Have students record the times into a table and calculate the fluid flow rate by dividing the volume by the time.

e. Repeat a – d for each solution and record this twice for each solution.

12. Multiphase solutions

a. Each student will add a volume of solution to the channel via the syringe two top syringes.

b. To get started, students will work on their priming skills by using different colored water to ensure they can prime the system accordingly. Once they have proved that, then students will add 5ml of two different solutions to the syringes, the students will then prime the chip and allow it to start to flow through the chip and out the tubing into the waste container.

c. To prime this, students will need two additional syringes and create a partial vacuum however you must prime the system, since it has two exit ports, you must prime them both at the same time, you will need two syringes and create the vacuum in both tubes at the same time. Through practice you will get this to both flow at the same time.

d. For the multiphase we will not be doing any calculation, just take observations notes and describe what is happening.

e. The chip will need to be cleaned before testing the next solution or a reaction will occur. To do so, at least 10 ml of NaCl need to pass through the chip, and followed by at least 10 ml of water, preferably deionized if you have it

f. Have students repeat the multiphase solutions part putting all the other combinations into the chip record what happens. As you can use what every you want solution wise that will flow through the chip, if you use what I used create the following trials with PAA on the left and PDADMA on the right.

(PAA 130 K will need to be diluted to a 1:50 ration with water)

i. PAA 1.8 K and PDADMA 100 K

ii. PAA 1.8 K and PDADMA 8.5 K

iii. PAA 130K and PDADMA 100 K

iv. PAA 130 K and PDADMA 8.5 K

g. Cleanup: The chip will need to be cleaned before testing the next solution or a reaction will occur. To do so, at least 10 ml of NaCl need to pass through the chip, and followed by at least 10 ml of water, preferably deionized if you have it. Do this the same way you had the over solution

flow through, but instead of letting gravity force the fluid down the channel, we will be using a partial vacuum. Use the syringe at the bottom of the apparatus, the one you use to prime the system and just allow that vacuum you create to pull the fluid through the chip. **DO NOT USE A SYRINGE PLUNGER AND PUSH THE FLUID THROUGH THE CHIP FROM THE TOP DOWN.**

Have students put the waste in an appropriate place, where the teacher says is ok, not the drain. Have them return the chips and put away clamps, syringes and return solutions.

13. Extension: Part 1

- a. Design a chip that allows two different solutions to mix at a meeting point and then separate again into two distinct different ending points. (Ex: would be taking two y shaped parafilm cut outs, have one upright and the other reflected on the y axis so it makes an "x" shape.
- b. Once you build that parafilm cut out, repeat steps 1-4.

14. Extension: Part 2

- a. Design a chip that allows only different primary colored water to mix and output the rainbow.
- b. This is particularly challenging, but it can be done.
- c. You will need a chip that produces in this order: Red, Orange, Yellow, Green, Blue and Purple water.
- d. Once you have your chip designed, repeat steps 1-4.

Lab Activity:

Name: _____

Date: _____ AP Physics

INTRO

Today we will be building microfluidic chips, we will be measuring flow rate, and we will observe what happens in multi solution systems. It is very important to follow the directions, be careful in construction, and ask questions.

Material List

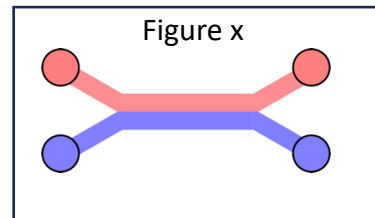
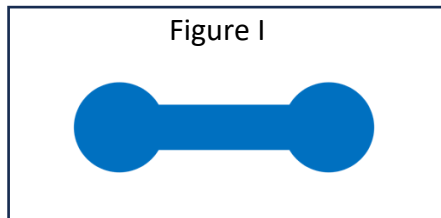
- Water
- Food color
- Microscope
- Parafilm
- Scissors
- Cricut*
- Plexiglass (1mm) [Amazon PET Plexiglass](#)
- A heating source (Ex: oven at 50 degree Celsius)
- Weight to help seal chip during curing phase
- Drill
- Drill bits
- Appropriate drilling surface (Ex: scrap wood)
- Microfluidic tubing [Microfluidic Tubing](#)
- Pipet Tips
- Syringes (1 or 10ml)
- Epoxy [2-Part Epoxy](#)
- Toothpick and scrap paper to mix Epoxy
- Test tubes to hold water
- Test tubes to hold coacervates
- Test tubes to hold Salt solution
- Area to store microchips to cure
- Chemicals including PDADMAC (8.5 kDa and 100Da), PAA (1.5 kDa and 130kDa), and salt (NaCl).

Procedure

Day One

In today's lab we will need to do the following:

- Locate all materials provided by the teacher
 - Part one material list
 - Plexiglass sheets (These are precut to 6 x 4 inch plastic sheets)
 - Parafilm (4x3 inch sheet)
 - Scissors
 - Paper clips or clamps
- 1. You will first remove the cover plastic off both sides of the plexiglass sheet. If you forget to do that the chip won't seal well.
- 2. Take the parafilm and cut it into a 4 x 3 inch rectangle, this is going to be your channel. You are going to design the single channel next. We want the parafilm to be one single piece. The white part needs to stay intact. The blue and red parts is the part that you want to have removed, the white square is the parafilm. Center this as much as you can to make a better seal. Once you have this complete, do this again with an x shaped design. The picture below should help visualize this. Save the x shape for later. As long as the shapes fit inside the 4x3 inch parafilm rectangle you will be good.



3. Place the cut out parafilm on the plexiglass. With a sharpie mark on the plexiglass where the inlet and outlet holes should be. Mark these on what will be the top of the chip, and mark where you will not hit the parafilm when you drill. We want the fluid to only go into the channel so center of the circle is idea for the access hole.
4. Once you have your hole marked, remove the parafilm and ask the teacher for the drill. You will need a 1/8-inch drill bit to cut the hole. On

a designated work area, place the plexiglass on the work area and use the drill and drill bit to make the inlet and exit holes. Have the person in your group who is well verse in using a drill do this part. IF you don't feel confident, ask the teacher or another classmate for help.

5. Once you have all the holes drilled, use an exact-o knife to clean up any residue left by the drilling process. We want both sides of the chip to be as clean as possible.
6. Now you will take the top layer and place it face down, followed by the parafilm layer, and finally the bottom layer, making a 3 layered chip. Make sure the holes drilled line up with the parafilm.
7. Now you can apply chips/clamps to keep everything in place. Once you have done this, turn it in to the teacher as they will perform the curing process for you.
8. Repeat steps 3-7 with the other designs you made with the parafilm and give the teacher your completed chips.

Day Two

9. Collect your chips from your teacher who has cured the chips for you over night. This next part is very important and requires delicate and precision.
10. When applying the pipet tips to the chip, we will be using two-part epoxy. When you are at this step, ask your teacher for the two-part epoxy and they will give enough for your chips. You will have to have a piece of scrap paper or cardboard to use as a mixing area. Use a toothpick to mix the epoxy. If it is not mixed properly the epoxy will not set and be watertight.
11. To apply the epoxy, first place the pipet tip directly over the drilled hole on the chip. With a steady hand, one person will hold the pipet in place, preferably applying pressure to the top as it sits flush to the plexiglass. The second person will put a smooth layer of epoxy around the pipet tip, making sure not to miss any spots and creating an airtight seal. Epoxy takes a least 5 minutes to set, so you need to make sure the tip does not move during the sitting phase, or it will not work. During this time, it is very easy for the tip to move and you to get epoxy into the channel leading to a deformed chip that will not work.
12. Once you have one tip set and is not moving, you can repeat steps 10 & 11 for the other pipet tips on your chip.
13. Once you have finished applying the pipet tips, complete these practice problems to make sure we can use the Poiseuille's Flow Rate formula correctly. Put your chip in a place that it will be safe and won't get broken, clean up your materials and return anything that should go back to the teacher.

$$F = \frac{\pi \Delta P r^4}{8 \eta L}$$

F= Flow Rate (m³/s)

P=Pressure (Pa)

η =Viscosity(Pa*s)

L= Length (m)

Problem #1

- A fluid is flowing down a channel at a rate of 0.0001 ml/s, how many micro liters is flowing per second?

0.01 ul/s

- If the channel is 8 cm long and 0.5 cm wide with a pressure that is changing and P₁ is 760mmHg and P₂ is 735 mmHg, what is the viscosity of the fluid?

1 ml/s → m³/s 1e⁻⁶

1 mmHg → 133.32 Pa

$$(1e^{-10}) = \frac{\pi(101325 - 97990.2)(0.0005)^4}{8\eta(0.08)}$$

$\eta = 102.3103 \text{ Pa} \cdot \text{s}$

- What substance is flowing?

Substance	η (Pa.s)
Air	10^{-5}
Water	10^{-3}
Ethyl alcohol	1.2×10^{-3}
Mercury	1.5×10^{-3}
Ethylene glycol	20×10^{-3}
Olive oil	0.1
100% Glycerol	1.5
Honey	10
Corn syrup	100
Bitumen	10^8
Molten glass	10^{12}

Corn Syrup

Problem #2

- A fluid is flowing down a channel at a rate of $.000001 \text{ m}^3/\text{s}$, how many micro liters is flowing per second?

1000 ul/s

- If the channel is 12 cm long and 0.99 cm wide with a pressure that is changing and P_1 is 760mmHg and P_2 is unknown, with a viscosity of 0.1 Pa*s, what is the new pressure?

$$\text{1 ml/s} \rightarrow \text{m}^3/\text{s } 1\text{e}^{-6}$$

$$\text{1 mmHg} \rightarrow 133.32 \text{ Pa}$$

$$(1\text{e}^{-10}) = \frac{\pi(101325 - P)(0.0005)^4}{8(0.1)(0.08)}$$

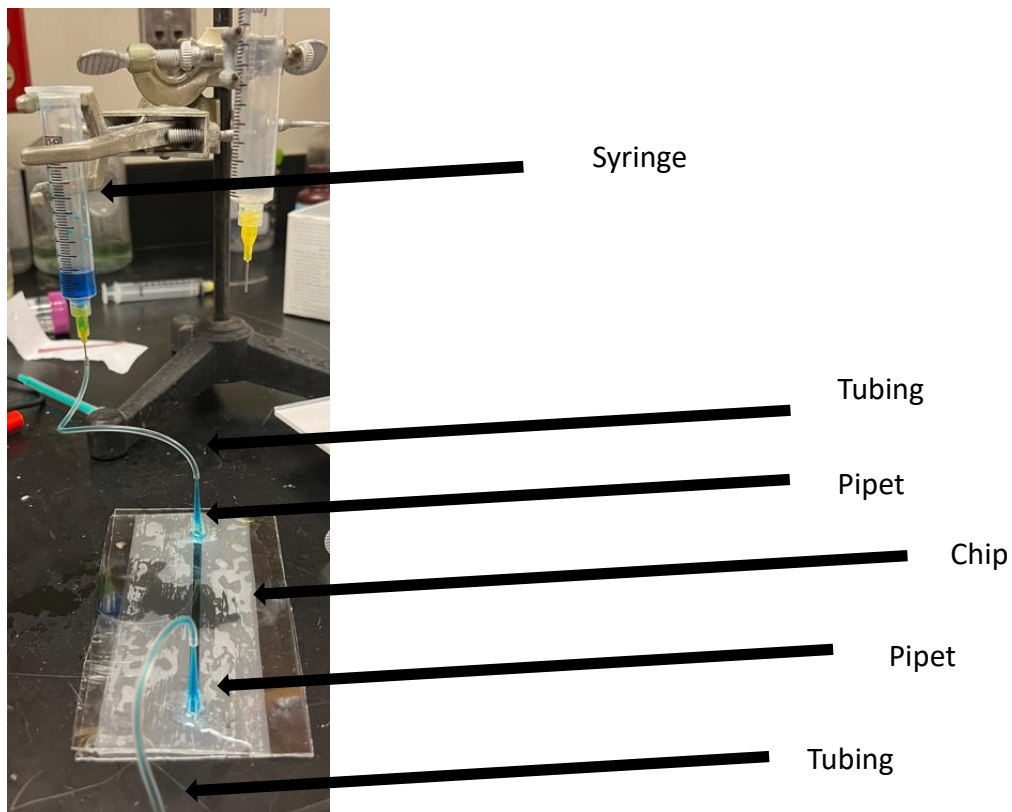
$$P = 101292.4051 \text{ Pa}$$

$$P = 759.7 \text{ mmHg}$$

Day Three

14. Gather your chips, get from your teacher the following materials.
 - i. Syringes, at least 2 for the single channel and 3-4 for the multi-channel chip.
 - ii. Microfluidic tubing 4 six-inch sections
 - iii. A ring stand.
 - iv. Two Test tube clamps for ring stands
 - v. A designated waste container designated by your teacher.
 - vi. Device to time, or video application.

15. Take the material you gathered and build this apparatus as depicted below:



16. Once you have built this structure, you are ready to collect flow rate data. To do so, you will need to follow the following.
- a. Pour at least 5 ml of solution A into the syringe. Next take another syringe that has a pipet tip on the end and attach it to the exit tube that is near the waste container and insert the syringe into the tubing. With that syringe you will be creating a partial vacuum. By doing so, you will be creating a pressure difference, overcoming capillary effect, and allowing the fluid to flow and drop out of the tub. Once you have the system primed and fluid is flowing into the priming syringe, you can take the syringe out of the tubing and let the fluid flow out the system and fall into a waste container. Put the fluid that the syringe also pulled through the system into the same waste container.
 - b. Once this get to 2ml on the syringe, start timing or recording the flow rate on the syringe, until it gets to 1ml. We only want to focus on the syringe for data collection during the single channel.
 - c. Repeat part b for when the fluid gets to 1ml and going to 0ml.
 - d. The chip will need to be cleaned before testing the next solution or a reaction will occur. To do so, at least 10 ml of NaCl need to pass through the chip, and followed by at least 10 ml of water, preferably deionized if you have it. Do this the same way you had the over solution flow through, but instead of letting gravity force the fluid down the channel, we will be using a partial vacuum. Use the syringe at the bottom of the apparatus, the one you use to prime the system and just allow that vacuum you create to pull the fluid through the chip. **DO NOT USE A SYRINGE PLUNGER AND PUSH THE FLUID THROUGH THE CHIP FROM THE TOP DOWN.**
 - e. Repeat a-d with all of the other solutions (B-F) and record your finding in the data table below.
 - f. Repeat steps a-d a second time and record those finding in the data table.

Solutions	Trial 2 (2ml-1ml) Seconds	Trial2 (1ml-0ml) Seconds	Average Flow Rate
Solution A	0.0077	0.0081	0.0079
Solution B	0.0030	0.0027	0.0028
Solution C	0.0071	0.0071	0.0071
Solution D	0.0063	0.0063	0.0063
Solution E	0.0054	0.0043	0.0049
Solution F	0.0025	0.0020	0.0023

SIMILAR RESULTS AS ABOVE

Solutions	Trial 2 (2ml-1ml) Seconds	Trial2 (1ml-0ml) Seconds	Average Flow Rate
Solution A			
Solution B			
Solution C			
Solution D			
Solution E			
Solution F			

17. Once you have the average Flow Rates, you will be using Poiseuille's Flow Rate formula to solve for the viscosity of each solution, you will need to measure the channel's width, and length. You will need to use the newly founded flow rate, and you will need to find the pressure difference. By using Bernoulli's equation, we can find the Pressure in each position as P_1 initially is 760 mmHg. You will need to find P_2 at the end of the 2ml – 1ml. (Convert Pressure to pascals, flow rate to m/s^2 , height to m)

Solutions	Flow Rates (ml/s)	Viscosity (Pa*s)	Solution Letter
PDADMA (8.5K)	0.004778	0.01475	E
PAA (130K)	0.00167	0.03187	F
WATER	0.008013	0.009802	A
PDADMA (100K)	0.002919	0.02730	B
PAA(1.8K)	0.007418	0.01074	C
NaCl	0.006391	0.01247	D

Work Shown

Solution A

Solution D

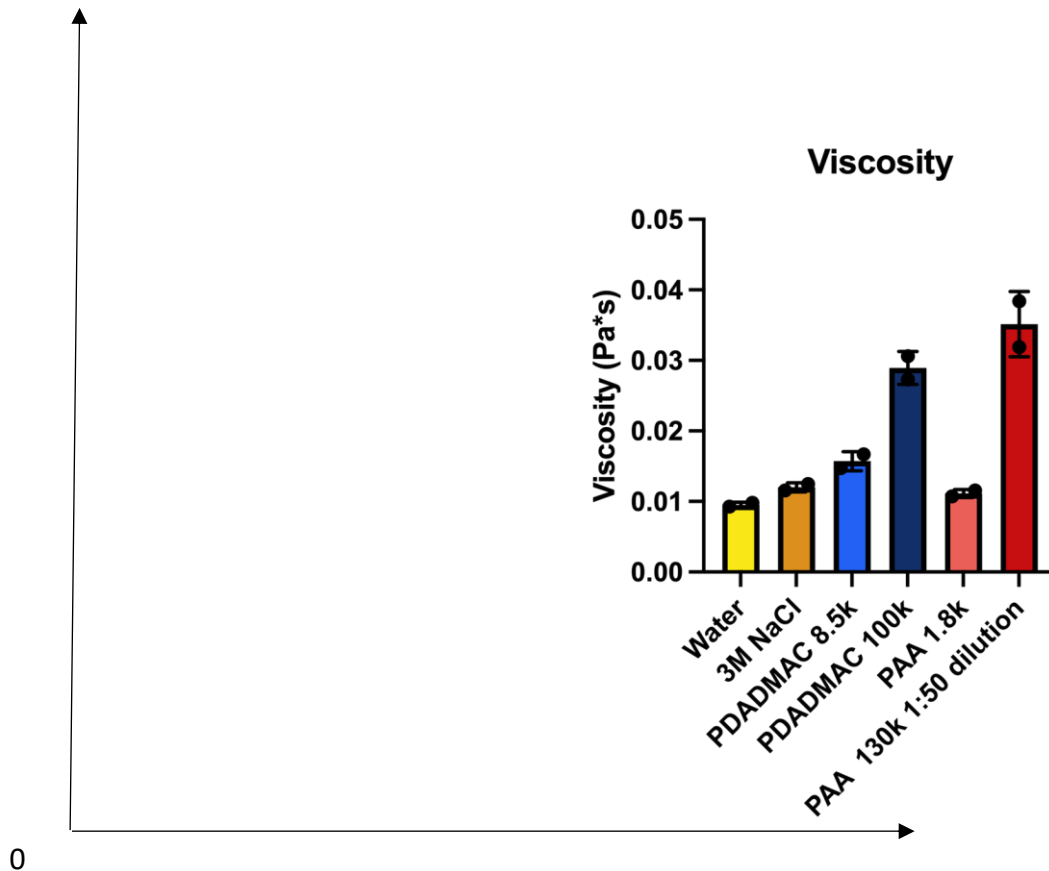
Solution B

Solution E

Solution C

Solution F

18. Once you have found the solution and its viscosity. Create a graph that relates the flow rate to the viscosity.



19. Now we will look at the multiphase channel. In the multiphase channel we will be getting the apparatus set up, just like in step 15, however, just having two inlet and two outlets.
20. Next you will be adding 5ml of one solution to one syringe, and 5ml of another solution to the other syringe. Keep the red colored solutions in one syringe, and the blue colored solutions in the other syringe. Hook up the priming syringe and pull the two solutions through the chip creating a partial vacuum.
21. Refer to step 16a when it comes to application and of the two system chip, just using two syringes that hold the two solutions and up to priming syringes. The X shape requires you to prime both exit points at the same time. It can be difficult to do. As your teacher for help if needed. However, you only need to do one trial of each situation. You do need to clean the chip after each trial.

22. Record what you see, if you have access to a mobile microscope, use that to image what is happening inside the channel in the table below.
23. Solutions to use: PDADMA (100K) with both PAA and the PDADMA (8.5K) with both PAA. State what you see.

Solutions	PAA 130K	PAA 1.8K
PDADMA 8.5K		
PDADMA 100K		

Conclusion:

24. What do you think was the most difficult part of this lab?
25. What surprised you about this lab?
26. What happened when you mixed PAA (polyanion) with PDADMA (polycation)? If you don't know, do some research, and tell us what happened. Be sure to site sources.