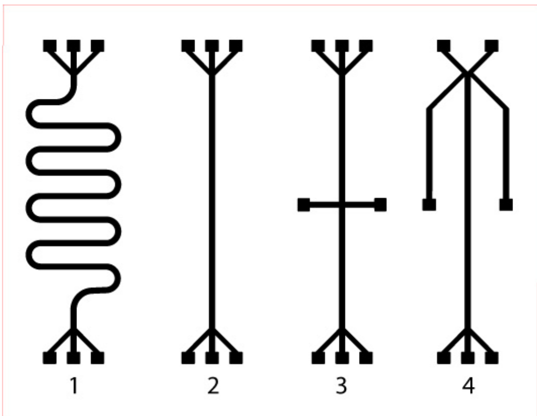
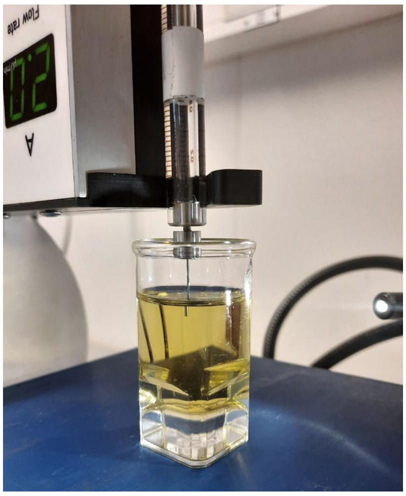
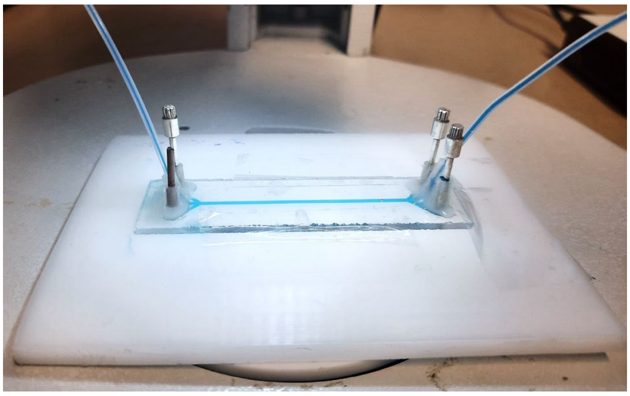
Introduction to Microfluidics and Lab-on-a-chip Systems (EEMN21)



Lab exercise:

Laminar flow, diffusion & surface tension effects





Biomedical engineering
LTH

Lab exercise:
Laminar flow, diffusion & surface tension effects

The purpose of this lab exercise is to gain hands-on experience of connecting and using microfluidic chips, as well as to observe and study some of the microfluidic phenomena that were introduced in the first lectures. Make notes and save your data. You then report your results in by free text in a quiz.

Preparations

Read these instructions and the lecture notes from lectures 2, 3 and 4. The following pages in the textbook (Introduction to BioMEMS by Albert Folch) may also be helpful: 97-106, 109-113 and 137-140. ***Do the compulsory quiz in Canvas before going to the lab as well as the preparatory exercises from the lab instructions***. You are required to reach 100% in the quiz. Please contact the instructors before the lab if you have troubles preparing.

Make sure that you are familiar with these concepts:

- The Reynolds number
- Pressure driven laminar flow and its flow profile
- Hydrodynamic focusing
- Fluidic resistance
- Diffusion
- Surface tension
- Buoyancy

If you have a laptop with Excel, MatLab or any other plotting tool that you can bring with you to the lab exercise, it will come in handy. To edit pictures like printing a scale on them or changing colours or contrast, ImageJ (also: Fiji) is recommended.

In the figure below, the channel dimensions are shown for the chips you will use in the lab:

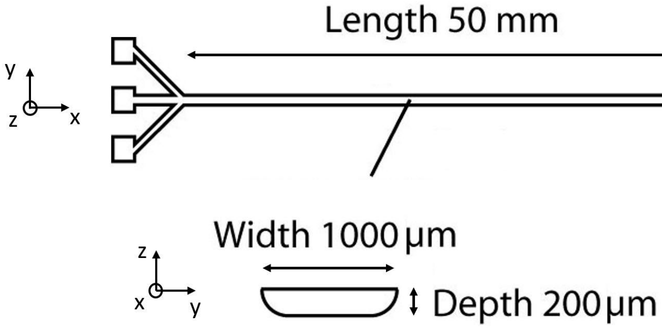


Fig. 1: Channel dimensions

1. Calculate what flow rate (µl/min) that gives a mean flow velocity of 1 mm/s in the straight, long channel.
2. What will the Reynolds number be? Will the flow be laminar or turbulent?
3. How much pressure is needed to drive this flow?
4. During the lab you will measure the diffusion constant for a dye molecule. Suggest a method to measure the diffusion constant and estimate suitable flow rate, channel structure and its inlet and outlet configuration (assuming that it is a small molecule).
5. Draw a force balance diagram for a hanging droplet in air and in oil.

Task 1. Laminar flow and diffusion

Your task is to study laminar flows and diffusion in microchannels. The setup depicted in Fig. 2 as well as a microfluidic channel etched in glass, with a glass lid bonded on top is available. You will generate flows with syringe pumps with disposable syringes and study the effects using a microscope. There will be no detailed instructions so you will have to find your own solutions to the task. The lab instructors will be available for discussions and questions.

During the lab, you will mainly use the channel layout number 2 as depicted on the front page. If you have the possibility, take some pictures that you can use for your report.

Fig. 2: Diffusion coefficient setup

1. Eyepiece
2. Rotation wheel to change view between eye piece and camera
3. Knob adjusting magnification
4. Larger knob adjusting the focus
5. Control for the light source
6. Chip holder with straight channel

Fig. 3: One of the two syringe pump for task 1

1. Knob to loosen and tighten the pushing unit (loosen it to insert syringes, tighten it to pump)
2. Screw to clamp syringes plunger holder
3. Syringe filled with water or dye

Do this:

a. Become acquainted with the lab equipment. Adjust the microscope so that you can visualize the channel in the ThorCam software. Set up the syringe pumps and use the control panel to set them to different flow rates. Check if the correct syringe size is set. Further instructions on how to use the pumps will be available.

b. Laminate two different liquids side by side. **Q1: Do the liquids mix? What is the mechanism? Argue whether turbulence can be involved. What happens for high and low flowrate?**

c. Try hydrodynamic focusing and vary the relative flow rates for the two liquids. **Q2: How is the flow affected when the relative flow rates are changed? What factors determine the widths of the streams?**

d. Measure and report the diffusion coefficient for one of the dyes you used. Find a suitable equation to derive the diffusion coefficient from the data you have available. **Q3: Describe the approach you used for the measurement and the resulting diffusion coefficient. What expression did you use to calculate the diffusion coefficient? Show data to support the measurement.** (Here is an easy way to measure distances in images https://eleif.net/photomeasure).

Task 2: Measure surface tension

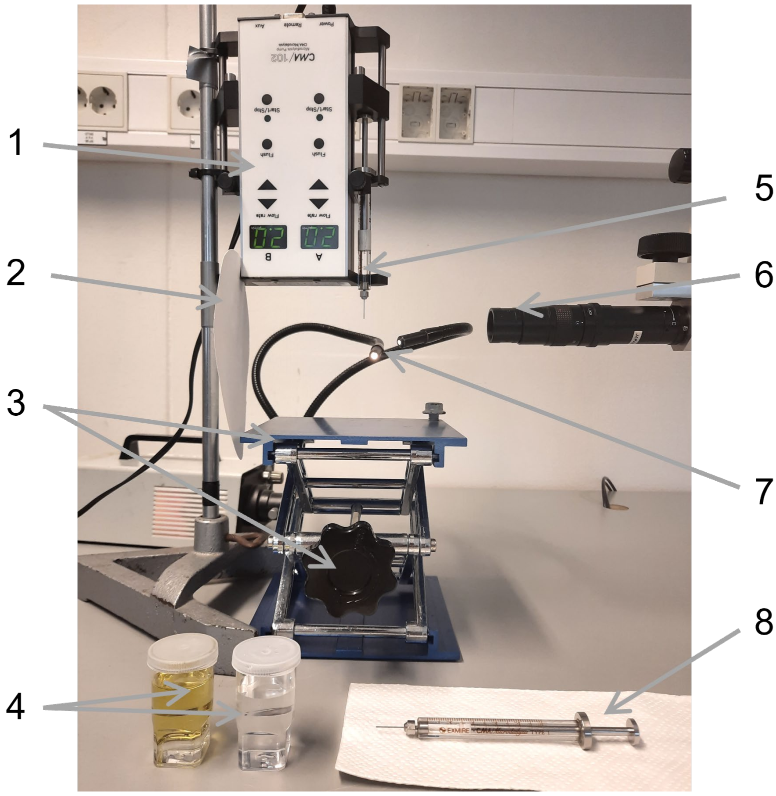


Fig. 4: Example setup for the surface tension experiments

1. Syringe pump
2. Paper screen for better imaging
3. Adjustable table to lower syringe tip into oil
4. Fluids: oil, water with surfactant
5. Syringe with water
6. Microscope with CCD camera connected
7. Snake light
8. Syringe for surfactant

Do this:

1. Fill the syringe with distilled water and clamp it into the syringe pump. Adjust the microscope setup using the two silver knobs and one black moving the microscope closer to the needle tip. Open ThorCam, connect the camera and start capture (top left). You should see a water drop at the tip of the needle in the ThorCam software clearly.
2. Generate a water drop hanging from the tip of the needle such that it is just about to fall. Image or draw the drop shape. Use the stop-capture function (top left) in the software to image at the right moment. **Q4: Draw or show an image of the drop the moment before it falls.**
3. Figure out a method to measure the average mass of a droplet. Note that you do not have a scale available. [Hint: you are allowed to use a stopwatch!]. Here is an easy way to measure distances in images: https://eleif.net/photomeasure.
4. Measure the surface tension of water. **Q5: Describe your chosen approach. What forces are in balance? Express the surface tension of a liquid in a formula by balancing forces at the rim of the needle.**
5. Generate water droplets submerged in oil to measure the water-oil interfacial tension. Image as described in 2.
6. Investigate the effect of adding a surfactant to the fluid. Make sure the needles tip is free of oil before starting the measurements.
7. **Q6: Explain why the surface tension differs for the fluids you investigated. Compare to literature values.**

Lab reporting **(Read this to pass on the first attempt and get one extra point on the exam!)**

- After the lab exercise, you summarize what you learnt individually by reporting in a free-text Quiz in Canvas.
- By formulating in your own words what you have observed, you will better internalize what you have learnt.
- The report corresponds to all the questions marked **Q#** posed throughout the instructions for each task.
- If you have done the lab together with a partner, name your lab mate in the report.
- Use maximum 200 words for each question and paste in graphics where needed.
- It is ok to use AI tools to find out how things work, but you must formulate what you have learnt in your own words. Note that e.g. ChatGPT is notorious for giving wrong but confident answers. Further, it is not a valid reference since it changes dynamically and is not traceable to the original source.
- Explain variables of equations unless it has been explained before.
- Be as precise as possible. Expressions like: “big, small, not really, kind of…“ etc. are unscientific.

All reports will be scanned for plagiarism.