CHEM-E8135 Microfluidics and BioMEMS,
Exam in MyCourses, 12.4.2020, 13:00-16:00

Return the exam to the return box before 16:00. A single pdf or docx file. If MyCourses crashes or otherwise as last resort, return by email ville.p.jokinen@aalto.fi

Exam has 5 questions, answer them all. Each questions is graded as max 6 points, but the max 30 exam points will be scaled to 40 course points (exam is 40% of course)

1. Microfluidic fundamentals 6p

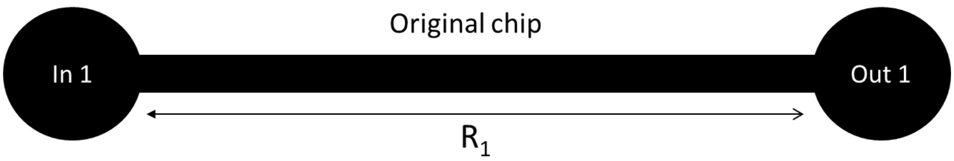
You have a simple channel (**same cross sectional dimensions throughout**) flowing from inlet 1 to outlet 1 with a total hydraulic resistance of R_1. You want to make a new design with an added extra channel that starts from the exact midpoint of the channel that goes to outlet 2. You want **99%** of the flow from inlet 1to go to outlet 1 and just **1%** to go to outlet 2.

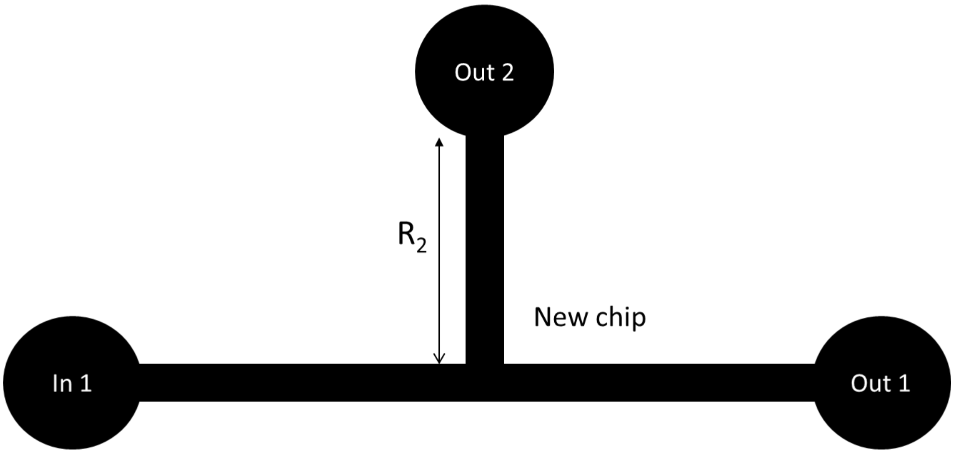
a) Lets call the hydraulic resistance of the newly added channel R_2. Qualitatively, explain whether R_2 should be bigger or smaller than R_1 and why. **2p.**

b) Quantitatively, what should be the hydraulic resistance R_2 as a function of R_1? **2p**

c) If the original channel had a cross section of 100 µm x 100 µm and a length of 1 cm, propose dimensions for the new channel to fulfill the criteria calculated in b). The length needs to be between 0.1 cm and 10 cm and the cross section needs to be between 1µm and 1mm. **2p**

(a design like this could be used for example to get a small aliquot for quality control of a chip that is producing something. Majority of the product goes to outlet 1 whereas an aliquot is directed to outlet 2.)





2. Materials 6p

Microfluidic chips are made from a wide variety of polymers, silicon, glass and other materials. The plethora of materials is both due to the “ultimate material” not being found yet and also due to different applications needing different properties.

Think of a situation where a new material X is being proposed to be used for fabricating microfluidic chips and you need to evaluate its suitability and potential. Make a list of the properties of material X that you would like to find out and briefly explain why these properties are important to know for considering material X for microfluidics.

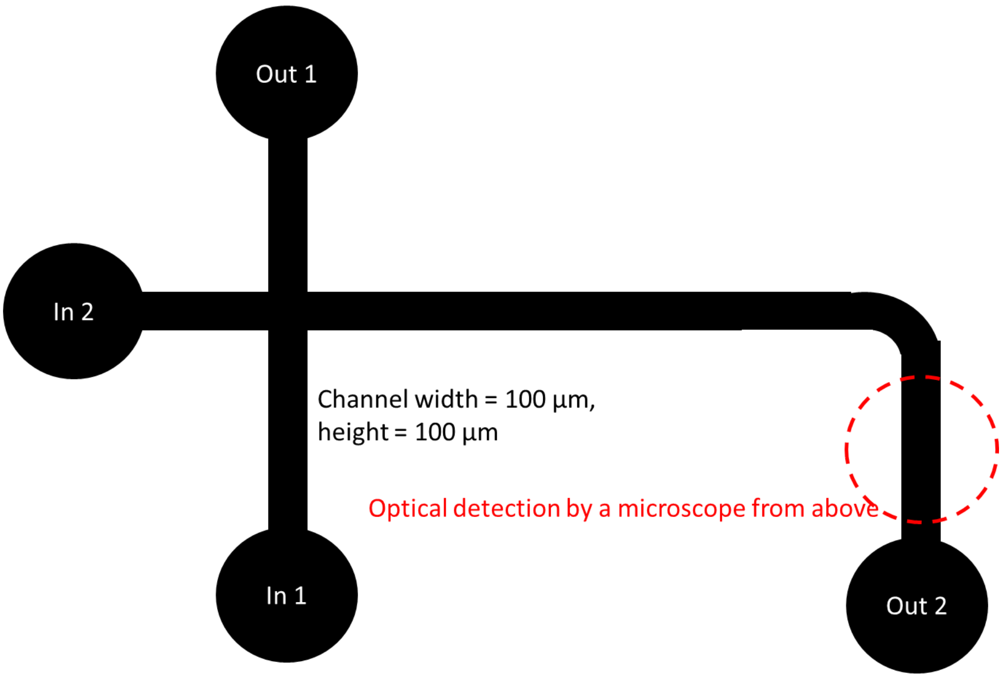
3. Microchip CE with optical detection 6p

You have fabricated the capillary electrophoresis chip shown in the image below. The chip consists of a cross injection (sample injected from Inlet 1 to Outlet 1) and the main separation channel (from Inlet 2 to Outlet 2). The chip is made from PDMS (3 walls) bonded on glass (1 wall), is operated by electroosmotic pressure and uses optical detection from above the chip.

In your first test run you get a disappointing performance: the separation efficiency is low and the detector struggles to detect the (poorly) separated peaks. Improve the design! (you need to stick to CE separation and optical detection, otherwise free to change geometry, materials etc.)

a) What could you change in your next version of the chip to improve the poor separation efficiency? **4p**

b) What could you change in your next version of the chip to improve the insufficient optical detection? **2p**



4. Biochip design

The figures below (figures continue to next page) show a microfluidic chip for detecting several different biomarkers from whole blood. It has three main components: 1. a gravity based module to separate the cells from the whole blood to create plasma, 2. biomarker area with capture lines for multiple biomarkers for optical detection and 3. suction chambers to actuate the flow.

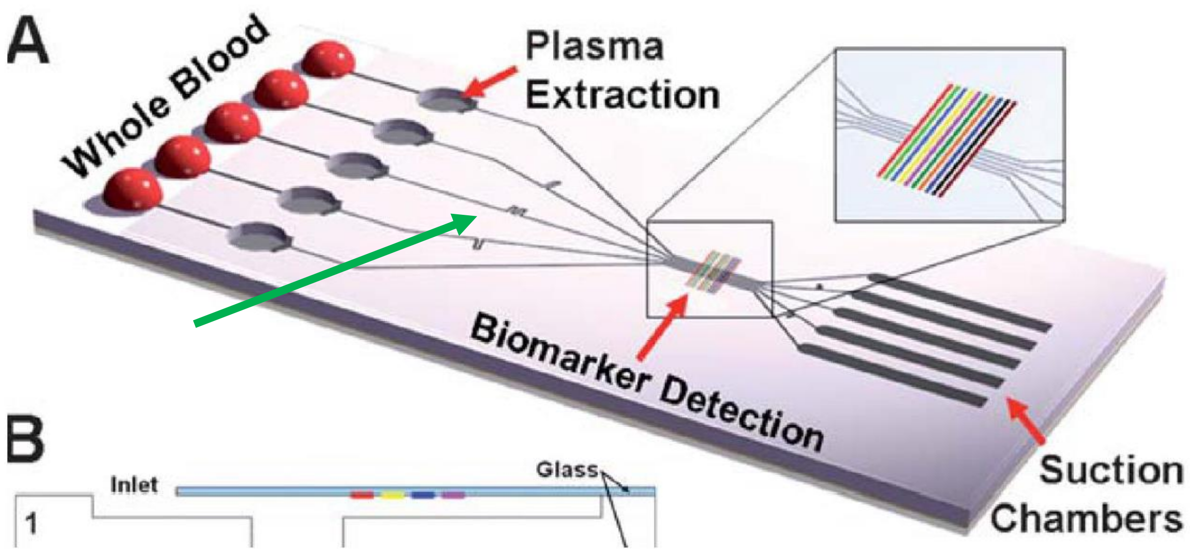
Answer the following questions. Acceptable answers are those that make sense with the figure and are based on sound reasoning from microfluidic principles, they do not need to match the article.

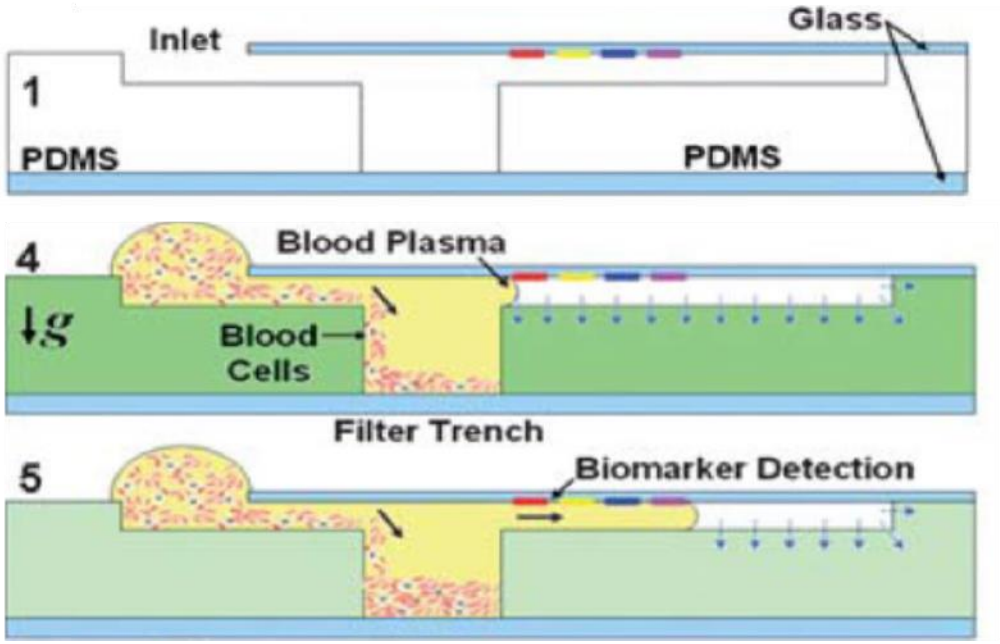
a) Which properties of PDMS are exploited in this design? **1p**

b) The green arrow in Figure A points to several small meander shaped channel extensions in some of the channels between the plasma extraction and the biomarker detection. What do you think is their purpose? **1p**

c) The gravity based module to remove cells (plasma extraction). If you had designed this chip and in testing found that some blood cells still got into the detection area, explain two different strategies based on simply changing the chip dimensions to improve the cell removal (do not add a second filter, these modifications need to improve the sedimentation based extraction). **2pts**

d) In general, what are the advantages of self-powered (e.g. capillary forces) chips? What are some possible disadvantages? **2pts**




Inlet
Glass
1
PDMS
PDMS
4
Blood Plasma
g
Blood
Cells
Filter Trench
5
Biomarker Detection

5. Essay covering the whole course: microfluidics for tacking Covid-19 6p
There are many aspects to fighting Covid-19, including:

1. Diagnosis: to detect whether a patient has Covid-19
2. Mutations/strains: to analyze emergence of new strains of Covid-19
3. Treatment development: to develop which drugs work to alleviate dangerous effects of Covid-19 has on e.g. lungs.
4. Vaccine development: to develop a vaccine that trains the immune system to fight off Covid-19
5. Vaccine production: to produce enough vaccines quickly without sacrificing quality control.

Write an essay on if and/or how microfluidics could be utilized in some or all of these areas. Utilize broadly the microfluidic concepts and language that you have learned on this course. Discuss the benefits and limitations of microfluidics and how they would apply.