Question Set 3

Fluidics - Basics

If you have any questions feel free to send an email: jonas.tegenfeldt@ftf.lth.se.

The suggested literature for this theme is quite extensive. However, the papers are overlapping and not everything in the papers is included in the course. Remember that the main task is to extract some key pieces of information as well as a general understanding of the basic principles of fluidics from the given literature.

Read the question and try to find the answer in the papers: Beebe's paper[1], Weigl's paper[2], and Quake's review[3]. The lectures also key information for the questions.

For a more comprehensive discussions on microfluidics there are at least two books that may be useful:

1. Nam-Trung Nguyen, Steven T Wereley: Fundamantals and Applications of Microfluidics (2006).

2. Henrik Bruus: Theoretical Microfluidics (Oxford Master Series in Physics) - (2007)

For the homework questions, note that they can be divided into two categories: Some mostly concern listing a few facts. These are labeled (F) and the expected answer should fit within five rows of text. Some are more focused on calculations or a qualitative argument. These are labeled (C). Here the answer may become more extensive due to the space taken up by equations.

The question labeled ** is more challenging than the others.

QUESTIONS ON MICROFLUIDICS

1. (F) What is the major difference between fluidics in the macro scale and fluidics in the micro scale? What are the implications for microfluidics?

2. (C) What is the Reynolds Number? What is the Reynolds Number in a typical microfluidic channel (assume water, velocity ~ 1mm/s, channels of size 10µm and room temperature)? What type of flow do you have in that case?

3. (F) What are the major means of moving sample and/or liquids in small channels? How do they scale with size of the channels?

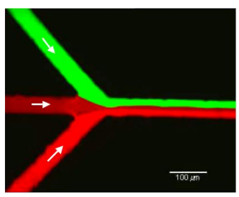
4. (C) A pressure difference can be applied between one free end and one end connected to vacuum or to an overpressure. What are the practical differences between these two approaches?

5. (C) A 50μm wide channel is connected in series with a 5μm wide channel. Assuming that each channel is 1mm long and 5μm deep, what is the expected flow rate of water through the channels at a pressure difference of 1 atm? What are the expected velocities?

6. (C) Same channels as in question 5, only that this time the channels are parallel. What are the expected flow rates through the channels at an applied pressure difference of 1 atm? Velocities?

7. (C) This time the device of questions 5 is connected to a device of question 6. Explain briefly how to calculate the flow rates and velocities in the channels.

8. (C) In a diffusive mixer (see figure to the right) the entrance velocities are 100μm/s for the outer channels (protein solution in standard buffer) and 1μm/s for the center channel (denaturant for the protein). With 50μm wide channels, what is the expected mixing time for the protein dissolved in the buffer solution entering in the outer channels?



9. (F) Taylor diffusion is due to the combined effect of a parabolic flow profile and diffusion. Explain how it improves the integrity of a sample plug in a flow system. Under some circumstances the flow behaves as if the spreading due to the parabolic flow profile is not there. Explain!

10. ** (C) Derive the expression for the velocity as a function of time of the fluid as it fills a small channel by capillary action. Consider a channel with open ends. Qualitatively, what happens if the end of the channel is closed?

References

1. Beebe, D.J., G.A. Mensing, and G.M. Walker, *Physics and Applications of Microfluidics in Biology*. Annual Review of Biomedical Engineering, 2002. **4**: p. 261-286.
2. Weigl, B.H., R.L. Bardell, and C.R. Cabrera, *Lab-on-a-chip for drug development*. Advanced Drug Delivery Reviews, 2003. **55**(3): p. 349-377.
3. Squires, T.M. and S.R. Quake, *Microfluidics: Fluid physics at the nanoliter scale*. Reviews of Modern Physics, 2005. **77**: p. 977-1026.