NAME: ________________________________

ID Number: ____________________________

BioE 121 Midterm Exam

November 19, 2009

This exam is a limited time, take-home test. It is designed to be completed in 1.5 hours so you shouldn't spend more than three hours working on this puppy, although it is not a problem if you want a little extra time. You do not have to complete the test in one sitting. You can use your notes, books, and the web for any information that you need.

You must do all your own work. Please show all of your steps for solving the problems and not just your solutions. Neatness helps me grade and puts me in a better mood.

Problem 1 – 40pts	Problem 2 – 30 pts	Problem 3 – 30 pts	Total

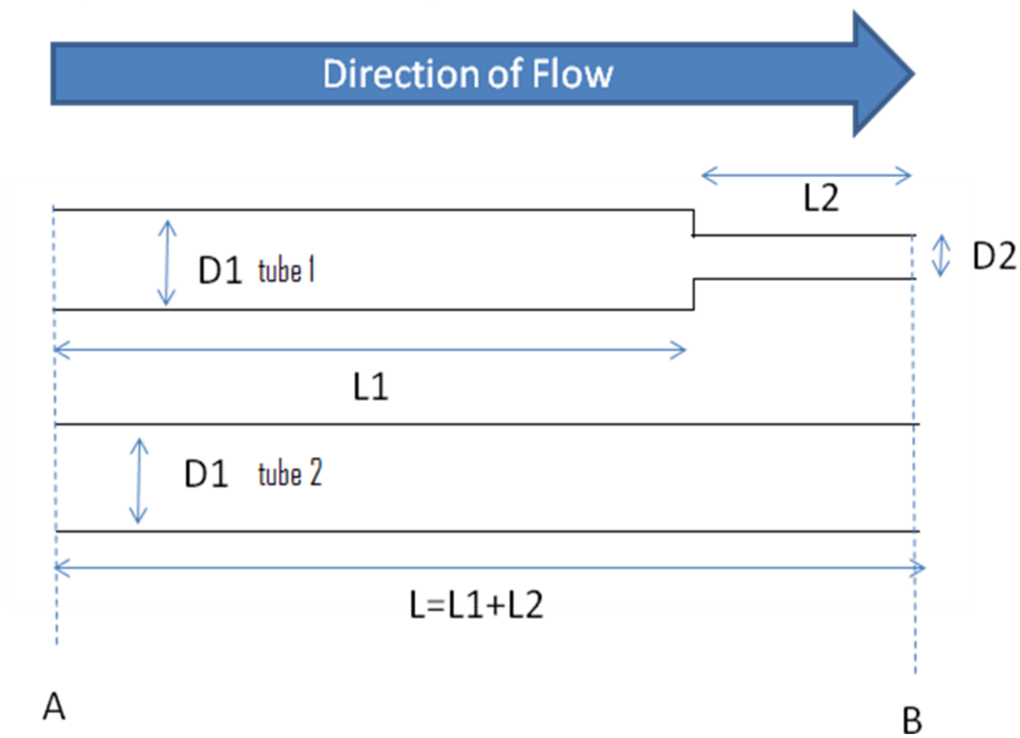
BioE 121 Midterm Name ______________________

Problem 1 (Fluid Mechanics) 40 pts

Electricity was once understood as a kind of fluid. Conceptually, this hydraulic analogy is still useful today: The "across-variable" voltage corresponds to the pressure drop ΔP and the "through-variable" current corresponds to the volumetric flow rate Q leading to an Ohm's law of fluid mechanics of the form $\Delta P = RQ$, where R is known as "fluidic resistance"

a) Derive the expression for the fluidic resistance R for a round pipe of diameter D and length L from Hagen-Poiseuille's law.

b) (Hint: In electronics we know how to deal with resistances in parallel and in series.). Compare two round tubes (tube1 and tube2, the wide and narrow segments of tube 1 are concentric) which are shown below in cross-section. Note that D2<D1. Assume that all flow is incompressible and the tubes are rigid.



a. For a given pressure drop between faces A and B calculate the volumetric flow through B for both tubes. In which tube will Q at B be higher?

b. Develop expressions for the maximum velocity in the two tubes. Which tube will generate the highest Vmax at B? How do the parameters L1 and L2 affect your results and tie in with the daily-life experience that you can spray water from a garden hose farther if you hold your finger over the end of the hose?

c. Now assume that a syringe pump is used to generate a fixed flow rate into each tube (analogous to a constant current source in electronics). For which tube is Q higher?

d. For which tube is Vmax at B higher? How do the parameters L1 and L2 affect your results? Compare the results you obtained and explain the difference between pressure-driven and volume-driven flow.

Problem 2 (Fabrication) 30pts

You'd like to pattern some really reactive metal (e.g. calcium) onto some generic substrate.

a.) Please explain why you cannot use standard Photolithography for the patterning.

You decide to evaporate the metal (evaporator in argon glove box) through a metal shadow mask but your desired features are so small (10 micron) that the machine shop cannot mill or laser-cut the mask for you. Thus you've decide to make a silicon shadow mask yourself by using photolithography to pattern a 0.2mm thin silicon wafer, and etching holes (for the metal to pass) all the way through it.

b.) Describe all the steps required to fabricate the silicon shadow mask in detail. Name reagents/gases wherever applicable. Provide schematic cross-sectional drawing with realistic estimates for the required thickness of masking layers used for etching.

c.) Assuming you wanted to run the entire mask-making process in the Berkeley Microlab, which tools would you need to get qualified on? Give tool type "e.g. e-beam evaporator" and Microlab name of machine (e.g. edwardseb3). [Several possible combinations of tools will give full score].

d.) Using internet resources and the information on the Berkeley Microlab homepage provide a ROUGH estimate as to how much that silicon shadow mask will cost your P.I. Take into account the cost of starting materials such as your wafer and the photomask with your pattern, Microlab fees and your time (grad students earn $2000 a month, undergrads work for free☺). Provide quotes and links wherever you can to corroborate your estimates but don't spend more than 30 minutes on this part!

Problem 3 (Dimensional Analysis) 30 pts

Consider a 2-D biosensor that uses an antibody-antigen reaction. The sample flows through a channel and the antigens in the sample have to react with the antibodies attached to the bottom of the channel. For an optimum design it is important to have the sample flow through the system as fast as possible while still allowing sufficient time for the antigens to diffuse and react with the antibodies. Use dimensional analysis to develop an order-of-magnitude design rule for the average velocity, U (m/s), of the sample through the channel. The other parameters of importance are assumed to be:

- The channel height, h (m)
- The length of the antibody surface, l (m)
- The diffusivity of the antigen, D (m^2/s)