Bioanalytical Microfluidics

Course Description
In recent years, microfluidics technology has revolutionized many important biological assays, such as blood tests, cell sorters, and singe-cell measurements. Inside microfluidic devices, fluids are highly predictable and controllable, making them versatile tools for liquid handling. This course aims to provide students with the confidence and know-how to design and use microfluidics devices in biological research. It will also provide an intuitive understanding of how microfluidics work, how they are made, and their applications for **bioanalytical assays of biomolecular and cellular systems**, including single-cell assays, immunological, and biochemical assays.

This course focuses on the use of soft-lithography for the design, fabrication, and deployment of simple microfluidic devices for **biomolecular and cellular applications**. Note: this course does not touch on organ-on-a-chip or macro-physiological applications. Soft-lithography is a versatile method for rapid prototyping of microfluidic devices and can be done with minimal dedicated equipment with minimal cost, making it highly accessible. As the course focuses on <u>teaching fundamental physical principles as it relates to questions in biological research</u>, students are assumed to have some background in the biological sciences <u>(have taken or is currently taking at least one biology course covering DNA, proteins, cells, microbes, or viruses)</u> and are <u>not</u> required to have a background in physical sciences. This course aims to provide students with an intuitive understanding of fluidic phenomena in microfluidic devices coupled with practical experience in microfluidic device design, fabrication, and deployment in biological research. Through a combination of lectures, hands-on labs, and a project that spans the cycle of device design, fabrication, and deployment, students will gain confidence in applying soft-lithography microfluidics to develop bioanalytical assays in any lab environment.

Learning Outcomes:
At the end of the course, students will be able to:

1. Demonstrate an intuitive understanding of the fundamental physical properties relevant to fluidic phenomena at micron-scales (pressure, viscosity, surface tension, diffusion, dielectrophoresis, hydrodynamic resistance, Capillary Number, Reynold's number)
2. Identify where and how microfluidics principles/phenomena can be applied to improve biological research/biotechnology.
3. Use soft lithography to design and fabricate microfluidic devices that are useful for bioscience applications.
4. Operate and troubleshoot microfluidic devices based on physical principles.
5. Communicate scientific ideas clearly to a microfluidics audience

Course Textbook
No single textbook covers all the material in a comprehensive manner for a diverse audience. All material will be provided in the course notes, handouts, presentation slides, and journal articles. For those looking for supplemental reading on the fundamental physical principles behind microfluidic phenomena, I recommend:

Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices by Brian J. Kirby

Course Evaluation plan

1. 2 Midterm Tests on theoretical understanding of microfluidic principles (LO 1-2, 2x15% of marks)

    - One hour open-book exam focused on application of physical principles on design and analysis of microfluidic devices.
    - One hour open-book exam focused on theory and application of physical principles of sensing and actuation in microfluidics and their biological applications.
2. Presentation of a paper on application of microfluidics to biological research (LO 5, 15% of marks)
    - Students will work in pairs to present a paper from peer-reviewed literature that utilized microfluidics principles to tackle a biological research problem. Students are graded by TAs according to a rubric emphasizing their explanation of the microfluidic principles at play and how it solves a research problem.
    - Students will give feedback via peer review, the quality of peer review will be graded by TAs according to a rubrick (5%)
3. Microfluidic device design competition (LO 3,4,5, 20% of marks in total)
    - Students will work in pairs to design, fabricate, and test a microfluidic device for a specific purpose. Teams will compete within the class for the best performing design, with a special reward for the winning team.
    - Students will be graded based on a written report documenting the design process and device performance.
4. Final Project: Design, implementation, presentation, and demonstration of microfluidic device for a specific function in biological research (LO 3,4,5, 35% of marks in total)
    - Students will work in pairs to come up with a biological research problem (or pick one from a provided list) that can be addressed with microfluidics devices, then iteratively design and test devices using soft-lithography over 5 weeks to come to a working solution. Students will submit a report describing their solution (15% of marks).
    - Students will explain their research problem and solution through a 10 minute presentation (including videos of their device functioning) (15% of marks).
    - Students will demonstrate their devices to their classmates and provide peer feedback for their clarity of communicating scientific ideas (5% of marks).

Course Format
Class will meet twice a week – 1 hour lecture in class room, and 2 hour practical in teaching lab. Meets in teaching lab will be involved with teaching soft lithography and design, fabrication, testing, troubleshooting of microfluidic devices for the device design competition and final project. Additional time in the teaching lab can be coordinated if needed.

Week	**Classroom**	**Teaching Lab**
1	Introduction and Overview (mentions complex devices, non-bioanalytical applications)	Lithography: Photoresist and Spin-coating
2	Inertia, Viscosity, and Reynold's Number Flow in a microchannel, Haagen Poiselle Eqn	Multi-layer photolithography, mask aligning, and mask drawing
3	Surface tension and Capillary Number Microfluidic mixing and Peclet number	PDMS molding, device bonding, surface treatments
4	Actuation/control - Dielectrophoresis, magnetophoresis, acoustophoresis *Midterm 1*	Cell trap device comp etition
5	Ultrahigh-throughput droplet microfluidics	Cell trap device competition
6	Case Studies of Microfluidics Applications – Molecular and cellular analytics	Final Project

7	Case Studies of Microfluidics Applications – Cellular analytics and modelling of biological systems	Final Project
8	Case Studies of Microfluidics Applications – Diagnostics and Lab on a chip *Midterm 2*	Final Project
9	Literature Presentations	Final Project
10	Literature Presentations	Final Project
11	Final Project Presentations	Final Project Demonstrations
12	Final Project Presentations	Final Project Demonstrations