***Microfluidics and Electrokinetics***

***Instructor***
Henry Chu
h.chu@ufl.edu
607-319-6298

***Course Description***

This course focuses on the fundamentals of microscale momentum and mass transport phenomena, with applications to common microfluidics and electrokinetics systems in recent research. Students, whose majors are and are not in chemical engineering, are welcome to take this course. Students taking this course are expected to have fundamental knowledge to solve ordinary differential equations and basic partial differential equations, although no prior knowledge in transport phenomena is required.

***Course Objectives***

This course will introduce students to key topics in microfluidics and electrokinetics via derivations and examples of the underlying momentum and mass transport phenomena. In terms of momentum transport, this course will cover the fluid flows in non-porous media and in porous media. In terms of mass transport, this course will cover nonionic and ionic solutes and particulates. The course has no homework and quizzes. Student performance is evaluated based on an individual research project. Following this course, students will be able to:

- Understand microfluidics and electrokinetics systems that are driven by a pressure gradient, an electric field, and a solute concentration gradient
- Formulate, solve, and analyze transport phenomena in typical microfluidics and electrokinetics setups
- Design microfluidics and electrokinetic systems for simulations and experiments
- Identify open research questions in microfluidics and electrokinetics and propose logical hypotheses and solutions
- Effectively present their identified open questions, hypotheses, and solutions to experts and non-experts

***Course Schedule***

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| Week 1: | Microfluidics in non-porous media: Navier-Stokes equation (NSE); Non-dimensionalization of NSE |
| Week 2: | Microfluidics in non-porous media: Boundary conditions; Steady flow problems |
| Week 3: | Microfluidics in non-porous media: Unsteady flow problems; Stokes first and second problem |
| Week 4: | Microfluidics in non-porous media: Lubrication approximation; Thin-film flows |
| Week 5: | Project consultation with the instructor |
| Week 6: | Microfluidics in porous media: Characterization of porous media |
| Week 7: | Microfluidics in porous media: Darcy and Brinkman equation |
| Week 8: | Fundamentals of electrokinetics: Nernst-Planck equation; Boltzmann distribution |
| Week 9: | Fundamentals of electrokinetics: Electric double layer; Poisson equation |
| Week 10: | E-field-driven electrokinetics: Electroosmotic flows; Derivations and applications |
| Week 11: | Project consultation with the instructor |
| Week 12: | Concentration gradient-driven electrokinetics: Diffusioosmotic flows; Derivations and applications |
| Week 13: | Individual particulate transport by electrokinetics: Electrophoresis and diffusiophoresis |
| Week 14: | Collective particulate transport by E-field, and pressure/concentration gradient: Hydrodynamic dispersion |
| Week 15: | Student oral presentation; Peers and instructor evaluation |

***Project***

Students will complete an individual project in this course with consultation with the instructor. The project involves an individual student to: (i) identify an open research question in microfluidics/electrokinetics, (ii) state the hypotheses, (iii) describe the approaches to test the hypotheses, and (iv) obtain some preliminary results. A student’s performance is evaluated based on her/his (a) 10-page project report that includes a summary, literature review, proposed hypotheses, descriptions of the approaches to test the hypotheses, and some preliminary results; and (b) 15-minute video-recorded oral presentation summarizing the project.