ME 546

Prerequisite: ME 303, 419, ME 400

ENG ME 546 Introduction to Micro/Nanofluidics

Spring 2020

Instructor

Prof. **Chuanhua Duan** (Course coordinator)
Lecture Location: TT 9:00 -10:45 am, COM 210
Contact info: duan@bu.edu
Office: 110 Cummington Mall, ENG 415
Office hours: Tue 11:00 -12:00 pm

Course Description

This course is an introductory graduate course in mechanical engineering. It aims to introduce unique transport phenomena and major applications of micro/nanofluidics to senior undergraduates and new graduate students. Topics include overview of micro/nanofluidics, scaling laws, intermolecular forces, surface tension and Marangoni flow, passive scalar transport, electrowetting, electrokinetics, chemical reaction in confined space, carbon nanofluidics, micro/nano fabrication, etc. Special emphasis will be focused on understanding fundamental mechanisms of transport phenomena at the micro/nanoscale.

Course Objectives

1. Develop a broad and deep understanding of transport phenomena at the micro/nanoscale
2. Understand major applications of micro/nanofluidics
3. Understand major methods to fabricate micro/nanofluidic devices
4. Be able to design and test new micro/nanofluidic devices for certain applications

Course Prerequisites

This course is open for graduate students and senior undergraduates. Students are expected to be familiar with fluid mechanics (ME 303 or equivalent), heat transfer (ME 419 or equivalent) and engineering mathematics with partial differential equations (ME 400 or equivalent).

Course Website

Under Blackboard: Use http://learn.bu.edu/.

Textbook

Brian Kirby, "Micro-and Nanoscale Fluid Mechanics: Transport in microfluidic devices", Cambridge University Press, 2010

[1] Subject to change. Check the course website for the latest version.

Other references:
1. Joshua B Edel and Andrew J deMello "Nanofluidics: Nanoscience and Nanotechnology", Royal Society of Chemistry, 2009
2. Patrick Abgrall and Nam-Trung Nguyen "Nanofluidics", Artech House, 2009
3. Jacob Israelachvili, "Intermolecular & Surface Forces", Academic Press
4. Handouts prepared by the instructor
5. Weekly reading taken from primary research literature

Class Schedule

Two lectures per week. Each lecture includes 80-minute lecture and 20-minutes application introduction or case studies. Attendance Homework (total 4 homework) and the corresponding due date/time (typically in class on Thursday) will be announced in lecture and posted on the course website. Homework submitted late will not receive credit. Lecture attendance is mandatory and will be counted in your final grade.

Projects and Exam

There will be two projects for this course. The topic of the first project is fixed while the topic of the second one (which is also the final project) will be chosen by the students from a list of topics that the instructor has prepared. Partners are encouraged, but no more than two people may work in the same team. There will be one midterm this semester. The exact date is listed in the syllabus. Midterm is open book, open notes. Calculators are allowed to use during exams but other electronic devices (cell phones, PDAs, laptops, etc.) are prohibited. The only valid reasons for missing the exam are: death in the immediate family, serious illness (documented by a physician), or a conflict with a scheduled Boston University event. If you feel that you have a valid reason for missing the midterm, you must petition to Prof. Duan for permission to take the make-up exam. This petition must be received **BEFORE** the regularly scheduled exam. Petitions are not always granted! If the petition is granted, a mutually convenient time for the make-up exam will be arranged. The make-up exam will be more difficult than the regularly scheduled one.

Collaboration Policy

Students are allowed (in fact, encouraged) to work together on the homeworks and in groups (at most two people in a team) on the projects. Working together means truly working together, exchanging ideas, NOT copying. Copying another's work is cheating, as is allowing someone else to copy your work. All quizzes and exams must be done by each student individually. Anyone caught cheating may be subject to disciplinary action by the Committee on Student Conduct of the College of Engineering. Also, anyone found guilty of cheating will receive a 0 for that particular grade. When in doubt, ask before you collaborate!

Grading Policy

Attendance 5% Project 1 15% Homework 30% Midterm 20% Final Project 30%

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Lecture and Exam Schedule[1] (total 28 lectures)

Week	Lecture	Date	Topics	Reading	Deadline
1	1	01/21	Introduction		
	2	01/23	Scaling law and Continuum Model	1.3 & 1.4 Ref.2. chapter 2.1.1	
2	3	01/28	Pressure driven flow in microchannels and equivalent circuits	2 & 3	
	4	01/30	Passive Scalar Transport (Diffusion, Dispersion, mixing) stokes flow	4	Project 1 starts
3	5	02/04	Surface tension related microfluidics I Introduction and capillary flow	1.5	
	6	02/06	Surface tension related microfluidics II droplet microfluidics and electrowetting	17.3	
4	7	02/11	Electrostatics and Electrical Double Layer	5.1&9	HW1
	8	02/13	Zeta potential and Surface Charge in Microchannels	10	
5		02/18	**Substitute Monday Schedule of Classes** **(no class)**		
	9	02/20	Electroosmosis in Microchannel	6	
6	10	02/25	Fundamental of Species and Charge Transport Chemical Separation in Microchannels	11 & 12	
	11	02/27	Particle Electrophoresis	13	
7	12	03/03	Ion Transport in Nanochannel I (Surface charge governed transport, Surface charge regulation, PNP equation)	11 and Ref.1 Chapter 1.2	HW 2
	13	03/05	Onsager Matrix for Nanofluidics	15	
9		**03/10**	**Spring Recess (no class)**		
		03/12			
8	14	03/17	Ion Transport in Nanochannel II (Current rectification, Ion Concentration Polarization)	Ref.1, chapter 8	Project 1 Due, Final Project Starts
	15	03/19	Electroosmosis in Nanochannel	Handout	
10	16	03/24	Midterm Review		
	17	03/26	Basic Fabrication Process	Ref. 2, Chapter 3.1.1	
11	18	03/31	**Midterm**		HW3
	19	04/02	Fabrication of Microfluidic Devices	Ref. 2, Chapter 3.1& 3.2	
12	20	04/07	Fabrication of Nanofluidic devices	Ref. 2, Chapter 3.2	
	21	04/09	Nanopore Based Resistive Pulse Sensing	Handout	
13	22	04/14	Water potential and Phase change Phenomenon at the nanoscale (evaporation, condensation, boiling)	Handout	
	23	04/16	Carbon Nanofluidics	Handout	
14	24	04/21	DNA Transport and Analysis	14 and Ref.1, chapter 9	HW 4
	25	04/23	Separation in Nanochannels	12.5 and Ref.1 Chapter 2	
15	26	04/28	Biochemical reactions in micro/nanoscale confined space	Handout	
	27	04/30	Final Project Presentation		Final Project Due
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