ME 546
Prerequisite: ME 303, 419, ME 400

ENG ME 546 Introduction to Micro/Nanofluidics

Spring 2022

Instructor
Prof. Chuanhua Duan (Course coordinator)
Lecture Location: MW 12:20 -2:05 am, COM 109
Contact info: duan@bu.edu
Office: 730 Commonwealth Ave, EMA 202C
Office hours: Tue 11:00 am -12:30 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). Non-ME students who have not taken these pre-requisite courses should discuss with the instructor at the beginning of the semester.

Course Website

1 Subject to change. Check the course website for the latest version.
Textbook
Other references:
2. Patrick Abgrall and Nam-Trung Nguyen "Nanofluidics", Artech House, 2009
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 Wednesday) 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%

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