

SECOND SEMESTER 2023-2024

Course Handout Part II

Date: 09-01-2024

In addition to Part-I (General Handout for all courses appended to the time table) this portion gives further specific details regarding the course.

*Course No.* : BITS F417

*Course Title* : Microfluidics and its applications

*Instructor-in-Charge* : Meenakshi V

*Co-Instructor* : Aravinda N Raghavan

**Scope and Objective of the Course:**

Microfluidics is about manipulating fluids in miniaturized systems at the micro / nano liter scale. This subject is now one of the frontiers in interdisciplinary research that has many applications; for example, in developing novel health care devices. An important advancement that has propelled research in this area is the ability to build micron scale structures using various techniques: soft- lithography, photolithography, Laser engraving, 3D printing, etc. In this course, a student will learn the physics behind microfluidic devices through lectures, computer simulations, lab work and by reading research articles.

Here is a glimpse of the topics that will be covered in this course: Dimensional analysis and scaling laws to understand the forces that are significant at microscale, Navier-Stokes equation, Convection- Diffusion equation, simulation of fluid flow in micro-channels, diffusion, mixing and separation of microfluids, controlling flows – pumps and valves, micro fabrication, principle behind microfluidics- enabled technologies such as ink-jet technology, lab-on-a-chip (paper) devices. Students will have the opportunity to conduct a project on a chosen topic by performing an experiment in microfluidics and the corresponding numerical simulation after hands on training in microfabrication.

**Learning outcomes**

1. Dimensional and scaling analysis of fluid flow.
2. Fabricating micron / nano scale structures using various techniques: soft-lithography, photolithography, Laser engraving.
3. Analyzing microfluidic flow using COMSOL - computer simulation.
4. Surveying the various applications of microfluidics.
5. Reading Research Articles to understand important and current developments.

**Text Book:**

*Micro- and Nanoscale Fluid Mechanics* by Brian J Kirby, Cambridge University Press, 2010.

**Reference Books:**

*A Brief Introduction to Fluid Mechanics,* by Donald F Young, Bruce R Munson, Theodore H Okishii and Wade W Huebsch, John Wiley & Sons, 2011.

*Theoretical Microfluidics*, by Henrik Bruus, Oxford Master Series in Condensed Matter Physics, 2008.

*Fundamentals of Microfabrication,* by Marc J Madou, Taylor & Francis, 2017.

*Computational Fluid Dynamics,* by John D Anderson (Jr), McGraw Hill, 1995.

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| **Lecture**  **No.** | **Topics to be covered** | **Chapter** |
| 1-2 | Introduction to microfluidics – Physics at the microscale, role of various intermolecular forces. | Chapter 1 (Henrik Bruus) |
| 3-6 | Buckingham П theorem, Dimensional analysis and scaling laws to understand fluid flow. | Appendix E (Textbook) Chapter 7 (Donald  Young et al) |
| 7-13 | Navier-Stokes equation and application to obtain certain exact solutions. | 1.1-1.4,  Chapter 2,  4.1  (Textbook) |
| 14-18 | Diffusion, mixing and separation of fluids in  Microsystems - Analysis of dispersion phenomena, Passive and active mixing, Chaotic mixing. | Chapter 4 (Textbook) |
| 19 -24 | Finite Difference and Finite Element Methods, Introduction to flow simulation using computers -  Meshing, discretization and simulation using COMSOL multiphysics software | Chapter 4 (Anderson) and Lecture Notes |
| 25-30 | Introduction to microfabrication techniques - Photolithography- etching – embossing, Soft-  lithographic patterning, mask design, Laser Engraving, Paper microfluidics | Chapter 1 (Madou) and Lecture Notes |
| 30-35 | Experimental flow characterization – Micro Particle Image Velocimetry, Fluorescent microscopy | Research Articles |
| 35-40 | Applications of microfluidics - Micropumps and microvalves, Lab-on-a-chip devices, micromixers | Research Articles |
| 41 | Conclusion |  |

**Evaluation Scheme**

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| **Component** | **Duration** | **Weightage**  **(%)** | **Date & Time** | **Nature of**  **Component** |
| Mid-semester exam | 90 min | 25% | 12/03 - 9.30 - 11.00AM | Closed Book |
| Lab - Hands on training on  microfabrication |  | 10% |  | Experimental  work |
| Lab Project work and  Presentation |  | 20% |  | Experimental  Work (Lab) |
| Simulation and  Demonstration |  | 10% |  | CAD Lab |
| Comprehensive exam | 3 hours | 35% | 08/05 FN | Closed Book |

**Chamber Consultation Hour:** To be announced in class.

**Notices:** All notices concerning this course will be displayed in CANVAS.

**Make-up Policy:** No makeup will be provided for any lab / simulation component. For mid-semester and comprehensive exam, make-up will be granted only for genuine health issues (with supporting document) and with prior permission.

**Academic Honesty and Integrity Policy:** Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

Instructor-in-charge