Modelling and Simulation of Physiological Flows

Overview

The course offers a comprehensive exploration into the fascinating world of fluid dynamics within the human body. It provides students with an in-depth understanding of how mathematical models and advanced computational simulations are used to study and analyse complex flow phenomena in various physiological systems. The course encompasses a wide range of topics, from the fundamentals of fluid mechanics to the application of computational fluid dynamics (CFD) techniques in cardiovascular, respiratory, and other biological processes. Through this course, students gain valuable insights into the significance of physiological flow modelling in medical diagnostics, treatment planning, and the development of innovative medical devices.

Key themes covered in the course include the introduction to physiological flows, fundamentals of fluid mechanics, and mathematical modelling of physiological flows using the Navier-Stokes and continuity equations. The course delves into the principles of CFD simulations, providing students with practical experience in using CFD software for physiological flow modelling. Specialized topics like cardiovascular flow modelling, heart valves and prosthetic device simulation, and respiratory flow modelling offer a deeper exploration of flow phenomena in specific physiological systems.

The course also addresses multi-physics and multi-scale modelling, fluid-structure interaction (FSI) in cardiovascular flows, and hemodynamic analysis for disease risk assessment. Students are introduced to patient-specific modelling techniques using medical imaging data, paving the way for personalized medicine applications. Moreover, the course discusses future trends in physiological flow modelling, including emerging technologies such as AI and machine learning in flow simulations.

Throughout the course, emphasis is placed on ethical considerations, challenges in the validation and interpretation of physiological flow models, and the potential limitations and future directions in the field. By the end of the course, students will have developed essential skills in mathematical modelling, CFD simulation, and data analysis, enabling them to contribute to medical research, improve patient care, and advance the frontiers of physiological flow modelling for better understanding and treatment of various medical conditions.

The foreign faculty of the course- Dr. Suvash C Saha of the University of Technology Sydney, Sydney, Australia, will deliver the contents of this course. Dr Saha is an active researcher in the field of Computational Fluid and Particle Dynamics (CFPD) applications to various human physiology, energy storage, heat and mass transfer, etc. He has demonstrated his technical knowledge, experience, and ability in teaching, consultancy, research, and training in the fields of CFPD, Fluid Mechanics, Thermodynamics, and Heat Transfer. The course is planned and offered as per the norms set by GIAN and IIT Kharagpur, Kharagpur (India).

Course Objectives

The primary objectives of the course are as follows:

- **Understanding Physiological Flow Phenomena:** Develop a comprehensive understanding of fluid dynamics within the human body and its significance in various physiological systems. Analyze the flow patterns, hemodynamics, and transport phenomena specific to cardiovascular, respiratory, and other biological processes.
- **Mathematical Modelling and Simulation Techniques:** Acquire knowledge of mathematical models governing physiological flows, including the Navier-Stokes equations and continuity equations. Learn to apply numerical methods and computational fluid dynamics (CFD) techniques for simulating and analyzing complex physiological flow phenomena.
- **Application in Medical Diagnostics and Treatment Planning:** Explore the practical applications of physiological flow modelling in medical diagnostics and treatment planning. Understand how physiological flow simulations contribute to assessing disease risk, optimizing treatment strategies, and designing medical devices.

- **Advancing Research and Innovation:** Equip students with skills to contribute to cutting-edge research in physiological flow modelling. Foster the development of innovative solutions for healthcare, personalized medicine, and advancements in understanding physiological processes.

Dates	**9-14 December 2024**
Location	**The course will be conducted via OFFLINE mode at IIT Kharagpur, Kharagpur (India).**
Course Schedule	*

9th Dec 2024 (Monday)	**Inauguration: 9.00 AM to 10.00 AM** **Lecture Module 1 & 2: 10:30 AM to 11:30 AM (1 hr)** Topic1: Introduction to Physiological Flows. Topic2: Fundamentals of Fluid Mechanics. **Hands-on Session/Tutorial 1: 11.45 to 12.45 PM (1 hr)** Topic: Overview of fluid dynamics in the physiological system and discussion on air and particle flow in the respiratory system **Hands-on Session/Tutorial 2: 3.00 to 4.00 PM (1 hr)** Topic: Governing equations and dimensionless parameters used in physiological flow
10th Dec 2024 (Tuesday)	**Lecture Module 3: 9:00 AM to 10:00 AM (1 hr)** Topic: Mathematical Modelling of Physiological Flows. **Lecture Module 4: 10:15 AM to 11:15 AM (1 hr)** Topic: Introduction to CFD Software. **Hands-on Session/Tutorial 3: 11.30 AM to 12.30 PM (1 hr)** Topic: Hands-on tutorial on using Ansys Fluent CFD software package with case studies: blood flow through arteries **Hands-on Session/Tutorial 4: 3.00 PM to 4.00 PM (1 hr)** Topic: Basics of geometry creation, mesh generation, setting boundary conditions, simulations and post-processing a simple flow simulation.
11th Dec 2024 (Wednesday)	**Lecture Module 5: 9:00 AM to 10:00 AM (1 hr)** Topic: Cardiovascular Flow Modelling. **Lecture Module 6: 10:15 AM to 11:15 AM (1 hr)** Topic: Respiratory Air and Particle Flow Modelling. **Hands-on Session/Tutorial 5: 11.30 AM to 12.30 PM (1 hr)** Topic: Set up a CFD simulation of blood flow in an artery with boundary conditions and analyze parameter effect in the simulation results. **Hands-on Session/Tutorial 6: 3.00 PM to 4.00 PM (1 hr)** Topic: Simulation of airflow in the upper and lower airways and analyze airflow patterns and pressure distributions.
12th Dec 2024 (Thursday)	**Lecture Module 7: 9:00 AM to 10:00 AM (1 hr)** Topic: Multi-Physics and Multi-Scale Modelling **Lecture Module 8: 10:15 AM to 11:15 AM (1 hr)** Topic: Fluid-Structure Interaction (FSI) in Respiratory Air Flows. **Lecture Module 9: 11:30 AM to 12:00 PM (1 hr)** Topic: Simulation of Hemodialysis and Drug Delivery. **Hands-on Session/Tutorial 7: 2.00 PM to 3.00 PM (1 hr)** Topic: Setting up an FSI simulation to observe blood flow and a flexible vessel wall and analyzing the influence of FSI on the flow patterns. **Hands-on Session/Tutorial 8: 3.15 PM to 4.15 PM (1 hr)** Topic: Constructing a patient-specific personalized CFD model for a specific patient case.
13th Dec 2024 (Friday)	**Lecture Module 10: 9:00 AM to 10:00 AM (1 hr)** Topic: Patient-Specific Modelling and Personalized Medicine. **Lecture Module 11: 10:15 AM to 11:15 AM (1 hr)**

		Topic: Future Trends in Physiological Flow Modelling. **Lecture Module 12: 11:30 AM to 12:00 PM (1 hr)** Topic: Ethical Consideration & Challenge in Physiological Flow Modelling. **Hands-on Session/Tutorial 9: 2.00 PM to 3.00 PM (1 hr)** Topic: Quantifying hemodynamic parameters in CFD results, analysing the impact of flow patterns on cardiovascular disease risk and discussion on potential treatment strategies based on the simulation findings. **Hands-on Session/Tutorial 10: 3.15 PM to 4.15 PM (1 hr)** Topic: Discussion on emerging trends and technologies in the field, exploring the integration of AI or machine learning in CFD simulations and presentation of findings and its applications.
	14th Dec 2024 (Saturday)	**9.30 AM-12 Noon:** Evaluation of Learning Outcomes (Examination/Test, Feedback) & Certificate distribution.
Who should attend?	• Anyone with a degree in Engineering or Science. • Student at all levels (B.Tech./B.Eng/B.Sc/M.Sc./M.Tech./MBA/Ph.D.) and faculty members/academic staff from universities and institutions. • Engineers, Scientists and Professionals working in industries, policy organizations and R&D institutions.	

Registration & Course Fee	**Registration may be made by accessing the following online link:** https://erp.iitkgp.ac.in/CEP/courses.htm **Following are the registration fees:** Faculty Members: ₹ 3000/- + 18% GST IIT Kharagpur Students: ₹ 1000/- + 18% GST Research Scholars/ Temporary staff of Research Project: ₹ 1000/- + 18% GST Outsider Students: ₹ 1000/- + 18% GST Industry Participants: ₹ 5000/- + 18% GST **Payment link shall be shared after the confirmation of selection.**
Accommodation	**Accommodation on sharing basis may be available on request in either of the following:** (i) SAM Guest House (D/B Double Occupancy – Rs. 600/- and D/B Single Occupancy – Rs. 500/-), or (ii) VSRC-1 (Rs. 150/- without bedding per bed), both located inside IIT Kharagpur Campus, on payment basis. **Accommodation request should be registered by filling up the following form online:** https://docs.google.com/forms/d/e/1FAIpQLSfuwDcFwlslT9DdMSPL39--udh28Fr2MoPBpADEvfKLUZUZrA/viewform?usp=sf_link **Last Date of online application:** 5th Dec 2024.

International Expert

Dr. Suvash C Saha, University of Technology Sydney, Australia

Dr Suvash C Saha is a Senior Lecturer of Mechanical Engineering in the School of Mechanical and Mechatronic Engineering, University of Technology Sydney (UTS), Australia. He received his PhD in Computational Fluid Dynamics from James Cook University, Australia. Then he undertook Postdoctoral training at the Queensland University of Technology, Brisbane, Australia. Dr Saha's current research activities focus on three key areas of (a) Computational Biomechanical Engineering which includes particle deposition, clearance and penetration into the lung surfactant, Red Blood Cell (RBC) deformation into the capillary vessels and aging effect on RBC deformation (b) Heat and Mass Transfer

including Phase Change Materials (PCM), Solar thermal energy technology, Natural convection heat transfer in buildings and other confined geometries, Scale analysis for the transient flow, and (c) Microfluidics modelling including inertial separation techniques.

Host Faculty:

Prof. Suman Chakraborty (https://en.wikipedia.org/wiki/Suman_Chakraborty) is Institute Chair Professor in the Mechanical Engineering Department of the Indian Institute of Technology Kharagpur, India and Sir J. C. Bose National Fellow as bestowed by the Department of Science and Technology, Government of India. He has been the Head of the School of Medical Science and Technology and the Dean of Research and Development of the Institute. His current areas of research include microfluidics, nanofluidics, micro-nano scale transport, with particular focus on biomedical applications including novel diagnostic technologies for affordable healthcare. Prof. Chakraborty is a recent winner of the National Award for Teachers presented by the Honourable President of India, Freeman Scholar Award from the American Society of Mechanical Engineers (ASME) and the Infosys Prize in the category of Engineering & Computer Science. Based on his outstanding research contributions, he has also featured in the list of top 100 Researchers across all disciplines in Asia in 2023 by the Asian Scientist Magazine and the top-ranked researcher in Mechanical & Aerospace Engineering in India as per research.com. He has been the recipient of the coveted Santi Swaroop Bhatnagar Prize in the year 2013, which is the highest Scientific Award from the Government of India. He has been elected as a Fellow of the American Physical Society, Fellow of the Royal Society of Chemistry, Fellow of the ASME – 3 of the leading International Academic Bodies. He is also a Fellow of all the Indian National Academies of Science and Engineering. He has been the recipient of the G. D Birla Award for Scientific Research, National Academy of Sciences India – Reliance Industries Platinum Jubilee Award for Application Oriented Research, Rajib Goyal Prize for Young Scientists, Indo-US Research Fellowship, Scopus Young Scientist Award given by Elsevier (Germany) for high citation of his research in scientific/technical Journals, and Young Scientist/ Young Engineer Awards from various National Academies of Science and Engineering, and recipient of Outstanding Teacher Award from the Indian National Academy of Engineering. He has also been an Alexander von Humboldt Fellow, and a visiting Professor at various leading Universities abroad. He has a large volume of impactful publications in top International Journals (550+) with high citations (17000+) as well as patents/ licensed technologies and a unique expertise in technology development for the under-served population and community health-care.

Course Coordinator	Local Coordinator, GIAN
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