Indian Institute of Technology Kanpur

Proposal for a New Course

1. Course Number: CE XXX
2. Course Title: Computational Fluid Mechanics for Civil Engineering Applications
3. Per Week Lectures: 3 (L), Tutorial: 0 (T), Lab: 0 (P), Additional Hours: 0; Credits: 3 × L + T + P + A = 9.
4. Duration of Course: Full Semester
5. Proposing Department: Department of Civil Engineering

   Other Departments/IDPs which may be interested in the proposed course: Mechanical Engineering, Chemical Engineering, Aerospace Engineering, Earth Sciences, Sustainable Energy Engineering.
6. Proposing Instructor: Subhadip Das (Hydraulics and water resources, Civil Engineering)
7. Overview of the Course: This course provides an introduction to the computational modelling techniques for hydrodynamic data acquisition from the flow field. The computational modelling covers the basic concepts of the Partial Differential Equations (PDEs), different types of PDEs, conservative and non-conservative forms, characteristics analysis/solution for 1st order and 2nd order linear and quasi-linear PDEs, harmonic functions and mean value theorem, Eulerian and Lagrangian approaches, fundamentals of numerical modelling, numerical stability, consistency and convergence criteria, finite difference and finite volume methods (FDM and FVM), Taylor series and discretization, solution techniques and numerical schemes for different types of PDEs, first and second order discretization techniques, numerical algorithms (SIMPLE, PIMPLE, PISO), numerical stability and convergence, matrix factorization and inversion techniques, tri-diagonal and penta-diagonal matrices, Kolmogorov's theory, turbulence modelling, steady and unsteady Reynolds Averaged Navier Stokes (RANS) equations, turbulence closure models (k-ε, k-ω, RST), Large Eddy Simulation (LES), Smagorinsky model, Direct Numerical Simulation (DNS), structured and unstructured meshing, boundary conditions, development of computational framework using MATLAB and OpenFOAM, implementation of CFD in various Civil Engineering applications. This course briefly covers the basic post-processing algorithms of acquired data from computational studies including time-averaging of data, Reynolds stress and shear velocity estimation, frequency response analysis.
8. Applications in Civil Engineering: Hydraulics and water resources engineering (river hydraulics, sediment transport, spillway flows, flood modeling, dam-break analysis), structural engineering (wind loading on structures, fluid–structure interaction, aerodynamic analysis of bridges and tall buildings), geotechnical engineering (seepage through porous media, groundwater flow, soil erosion and piping analysis), transportation engineering (vehicular aerodynamics, tunnel ventilation, pollutant dispersion in urban streets), environmental engineering (air and water pollution dispersion, thermal comfort, wastewater treatment, atmospheric boundary layer flows).
9. Objectives: The primary objective of this course is to provide students with a foundational understanding of computational fluid mechanics and modern numerical techniques for solving fluid flow problems. The course is designed to be interdisciplinary and will be applicable to students from different backgrounds, especially from different specializations in Civil Engineering. A major component of the course will involve a computational project in which students will apply CFD tools or develop a CFD code to investigate a problem related to their own specialization or research interest. Through this project, students will also get familiarized with the full workflow of a research project including literature review, computational modelling, data acquisition, post-processing, validation using literature, and technical report preparation.
10. Pre-requisites: Basic understanding of hydraulics and fluid mechanics is required. Students should have some experience of computer programming using Python or C.

11. Short summary for inclusion in the Courses of Study Booklet: This course provides foundational understanding to the computational modelling for fluid dynamic research studies. The computational modelling covers the fundamentals of the Partial Differential Equations (PDEs), Eulerian and Lagrangian approaches, finite difference and finite volume methods, numerical algorithms (SIMPLE, PIMPLE, PISO), numerical stability and convergence, RANS equation and turbulence closure models, LES and Smagorinsky model, DNS. This course briefly covers the basic post-processing algorithms of acquired data from computational studies including time-averaging of data, velocity fluctuation, Reynolds stress, shear velocity estimation, frequency response analysis.

12. Recommended books:

- *Computational Fluid Dynamics* by John D. Anderson, Jr. McGraw-Hill, Inc.
- *An Introduction to Computational Fluid Dynamics: The Finite Volume Method* by H. K. Versteeg, W. Malalasekera. Pearson Education.
- *Computational Fluid Dynamics* by Klaus A. Hoffmann, Steve T. Chiang. Engg. Education System.*Fluid Mechanics and Fluid Machines* by S.K. Som and G. Biswas. Tata McGraw–Hill.
- *The Finite Volume Method in Computational Fluid Dynamics* by F. Moukalled, L. Mangani, M. Darwish. Springer.
- *Fluid Mechanics.* P. K. Kundu and I. M. Cohen. Academic press.
- *Viscous Fluid Flow* by Frank M. White. McGraw-Hill, Inc.

13. Course content and tentative lecture plan (40hrs)

Sl No.	Topics	Details	Hours of lectures
1	PDEs	Classification of PDEs, conservative and non-conservative forms, linear and quasi-linear PDEs, Eulerian and Lagrangian approaches, derivation of Navier-Stokes Equation.	7
2	FDM, FVM	Taylor series and discretization algorithm, numerical stability analysis, first and second order discretization schemes, numerical stability and convergence.	6
3	Numerical techniques	Numerical algorithms (SIMPLE, PIMPLE, PISO), tri-diagonal and penta-diagonal matrices, matrix factorization and inversion techniques.	8
4	Turbulence	Reynolds Averaged Navier Stokes (RANS) equation, turbulence closure models, basics of LES and DNS.	8
5	CFD modelling	Development of computational framework using MATLAB and OpenFOAM.	6
6	Data analysis	Post-processing algorithms of acquired data: time-averaging, velocity fluctuations, Reynolds stresses, Quadrant analysis, shear velocity estimation, frequency response analysis.	5

Dated: May 28, 2026 Proposer: Subhadip Das

Dated: DPGC Convener:

The course is approved / not approved

Chairman, SPGC
Dated: