COMPUTATIONAL FLUID DYNAMICS AND HEAT TRANSFER

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PRE-REQUISITES : First and Second year Mathematics Courses. The basic core course in Fluid Mechanics and a basic core course in Heat Transfer

INTENDED AUDIENCE : BTech (UG) in Mechanical. Chemical and Aerospace; MSc in Mathematics; MTech (PG) in Mechanical (Fluids and Thermal), MTech in Aerospace Engineering

INDUSTRIES APPLICABLE TO : DRDO Labs, Some CSIR Labs, BHEL, Thermax, GE etc

COURSE OUTLINE :

This course is an effort to cover a range of topics, - from elementary concepts for the uninitiated students to state-of-the-art algorithms useful for the practitioners. The contents begin with preliminaries, in which the basic principles and techniques of finite difference (FD), finite volume (FV) and finite element (FE) methods are described using detailed mathematical treatment. The methodologies are explained using step-by-step calculations. The popular CFD solvers, such as SIMPLE and MAC have been discussed in a detailed manner so that the learners can handle such programming paradigms with confidence. Some fundamental mathematical aspects of turbulent flows have been explained to enable the learners modeling the complex turbulent flows and associated heat transfer.

ABOUT INSTRUCTOR :

Prof. Gautam Biswas is presently a Professor of Mechanical Engineering at the Indian Institute of Technology Kanpur. Earlier, he has been the Director of Indian Institute of Technology Guwahati, and Director of the CSIR-Central Mechanical Engineering Research Institute at Durgapur. He was the G.D. and V.M. Mehta Endowed Chair Professor, and Dean of academic affairs at IIT Kanpur. The research group of Professor Biswas at IIT Kanpur identified the phenomenon of Rayleigh-Taylor Instability during the bubble formation in film boiling. This was a significant addition to the classical theory, based on Taylor Helmholtz instability. Another seminal contribution of his group is identification of zone of large bubble entrapment and underlying physics during the complete coalescence of a falling drop on a liquid surface. Professor Biswas is the author of more than 150 publications in the International Journals. He has completed guidance of 23 PhD theses.He was a Humboldt Fellow in Germany in 1987-88 and JSPS invited fellow in Japan 1994. He is a Fellow of the American Society of Mechanical Engineers (ASME). He has served a full term as the Associate Editor of the Journal of Heat Transfer (Trans ASME). He was a Guest Professor at the University of Erlangen-Nuremberg in 2002. Currently he is Associate Editor of a well-known CFD-Journal, - Computer and Fluids.Prof Gautam Biswas is a Fellow of the all three major Science Academies of India, such as, the Indian National Science Academy (INSA), New Delhi, the Indian Academy of Sciences (IAS, Bangalore) and the National Academy of Sciences India (NASI, Allahabad). He is a Fellow of the Indian National Academy of Engineering (INAE) and Institution of Engineers India (IEI). He has been awarded the esteemed J.C. Bose National Fellowship by the Department of Science and Technology, New Delhi in 2011. Prof. Biswas was bestowed with Distinguished Alumnus Award by BESU (now IIEST, Shibpur) in the year 2013. He has been awarded the Distinguished Alumnus Award by the Indian Institute of Technology Kharagpur in 2016. Prof. Biswas was conferred Honorary Doctorate (Honoris Causa) by National Institute of Technology Agartala, India, in 2017. He has been conferred Honorary Doctorate by the Aristotle University of Thessaloniki, Greece, in 2018.

COURSE PLAN :

Week 1: Introduction about the Course; Finite Difference Method (preliminaries); Explicit, Implicit, ADI Formulation

Week 2: Stability Analysis; Conservative and Transportive Properties

Week 3: Upwinding, Artificial Viscosity, Second Upwind; Higher order Upwinding and some Important Issues

Week 4: Applications of Knowledge and Setting up an Algorithm; Finite Volume Method (FVM-preliminary concepts)

Week 5: FVM-Equations with First Derivatives; FVM-Equations with Second Derivatives

Week 6: Finite Element Method (FEM-Preliminary Concepts); FEM-Galerkin Weighted Residual Method

Week 7: FEM-Elemental contributions and formation of Global Matrix; Vorticity Stream Function Approach (Formulation and Algorithm)

Week 8: Vorticity Stream Function Approach (Application to Curvilinear Geometry); SIMPLE Algorithm (Continuity and Momentum Equations)

Week 9: SIMPLE Algorithm (Momentum Equations and Pressure Solver); MAC Algorithm (The MAC Method and Discretization of the Equations); MAC Algorithm (Pressure - Velocity Iteration and the Solution)

Week 10: MAC Algorithm (Solution of Energy Equation); A Finite Volume Method to solve NS Equations in 3D Complex Geometry (Part-1); A Finite Volume Method to solve NS Equations in 3D Complex Geometry (Part-2)

Week 11: A Finite Volume Method to solve NS Equations in 3D Complex Geometry (Part-3); Turbulent Flow and Heat Transfer (preliminaries); Prandtl's mixing length and universal velocity profile

Week 12: Mathematical Approaches to Turbulent Flows-1; Mathematical Approaches to Turbulent Flows-2; Advanced RANS Models; Large Eddy Simulation (LES) of Turbulence