COMPUTATIONAL FLUID DYNAMICS AND HEAT TRANSFER

PROF. GAUTAM BISWAS
Department of Mechanical Engineering
IIT Kanpur

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

Introduction To Computational Fluid Dynamics Iit Kanpur

American Institute of Chemical Engineers

Introduction To Computational Fluid Dynamics Iit Kanpur:

Introduction to Computational Fluid Dynamics Atul Sharma,2016 This book is primarily for a first one semester course on CFD in mechanical chemical and aeronautical engineering Almost all the existing books on CFD assume knowledge of mathematics in general and differential calculus as well as numerical methods in particular thus limiting the readership mostly to the postgraduate curriculum In this book an attempt is made to simplify the subject even for readers who have little or no experience in CFD and without prior knowledge of fluid dynamics heattransfer and numerical methods The major emphasis is on simplification of the mathematics involved by presenting physical law instead of the traditional differential equations based algebraic formulations discussions and solution methodology The physical law based simplified CFD approach proposed in this book for the first time keeps the level of mathematics to school education and also allows the reader to intuitively get started with the computer programming Another distinguishing feature of the present book is to effectively link the theory with the computer program code This is done with more pictorial as well as detailed explanation of the numerical methodology Furthermore the present book is structured for a module by module code development of the two dimensional numerical formulation the codes are given for 2D heat conduction advection and convection The present subject involves learning to develop and effectively use a product a CFD software The details for the CFD development presented here is the main part of a CFD software Furthermore CFD application and analysis are presented by carefully designed example as well as exercise problems not only limited to fluid dynamics but also includes heat transfer The reader is trained for a job as CFD developer as well as CFD application engineer and can also lead to start ups on the development of apps customized CFD software for various engineering applications Atul has championed the finite volume method which is now the industry standard He knows the conventional method of discretizing differential equations but has never been satisfied with it As a result he has developed a principle that physical laws that characterize the differential equations should be reflected at every stage of discretization and every stage of approximation This new CFD book is comprehensive and has a stamp of originality of the author It will bring students closer to the subject and enable them to contribute to it Dr K Muralidhar IIT Kanpur INDIA Introduction to Computational Fluid Dynamics Atul Sharma,2021-08-26 This more of physics less of math insightful and comprehensive book simplifies computational fluid dynamics for readers with little knowledge or experience in heat transfer fluid dynamics or numerical methods The novelty of this book lies in the simplification of the level of mathematics in CFD by presenting physical law instead of the traditional differential equations and discrete independent of continuous math based algebraic formulations Another distinguishing feature of this book is that it effectively links theory with computer program code This is done with pictorial as well as detailed explanations of implementation of the numerical methodology It also includes pedagogical aspects such as end of chapter problems and carefully designed examples to augment learning in CFD code development application and analysis This book is a valuable

resource for students in the fields of mechanical chemical or aeronautical engineering **CRC Handbook of Thermal Engineering** Raj P. Chhabra,2017-11-08 The CRC Handbook of Thermal Engineering Second Edition is a fully updated version of this respected reference work with chapters written by leading experts Its first part covers basic concepts equations and principles of thermodynamics heat transfer and fluid dynamics Following that is detailed coverage of major application areas such as bioengineering energy efficient building systems traditional and renewable energy sources food processing and aerospace heat transfer topics The latest numerical and computational tools microscale and nanoscale engineering and new complex structured materials are also presented Designed for easy reference this new edition is a must have volume for engineers and researchers around the globe Basics of Fluid Mechanics and Introduction to Computational Fluid Dynamics Titus Petrila,Damian Trif,2004-12-15 The present book through the topics and the problems approach aims at filling a gap a real need in our literature concerning CFD Computational Fluid Dynamics Our presentation results from a large documentation and focuses on reviewing the present day most important numerical and computational methods in CFD Many theoreticians and experts in the field have expressed their terest in and need for such an enterprise This was the motivation for carrying out our study and writing this book It contains an important systematic collection of numerical working instruments in Fluid Dyn ics Our current approach to CFD started ten years ago when the Univ sity of Paris XI suggested a collaboration in the field of spectral methods for fluid dynamics Soon after preeminently studying the numerical approaches to Navier Stokes nonlinearities we completed a number of research projects which we presented at the most important inter tional conferences in the field to gratifying appreciation An important qualitative step in our work was provided by the dev opment of a computational basis and by access to a number of expert softwares This fact allowed us to generate effective working programs for most of the problems and examples presented in the book an pect which was not taken into account in most similar studies that have already appeared all over the world **Introduction to Computational Fluid Dynamics** Pradip Niyogi,2006 Introduction to Computational Fluid Dynamics is a self contained introduction to a new subject arising through the amalgamation of classical fluid dynamics and numerical analysis supported by powerful computers Written in the style of a text book for advanced level B Tech M Tech and M Sc students of various science and engineering disciplines It introduces the reader to finite difference and finite volume methods for studying and analyzing linear and non linear problems of fluid flow governed by inviscid incompressible and compressible Euler equations as also incompressible and compressible viscous flows governed by boundary layer and Navier Stokes equations Simple turbulence modelling has been presented *Computational Fluid Flow and Heat Transfer* K. Muralidhar,T. Sundarajan,2003 Numerical Methods in Laminar and Turbulent Flow ,1995 *Computational Fluid Dynamics '94* Siegfried Wagner,1994 This two volume work consists of the proceedings of the invited lectures and the special technological sessions of the Second European Computational Fluid Dynamics Conference September 94 Stuttgart Germany **Defence Science Journal** ,2006

An Introduction to Computational Fluid Dynamics e-book H. Versteeg,W. Malalasekera,2007 This established leading textbook is suitable for courses in CFD The new edition covers new techniques and methods as well as considerable expansion of the advanced topics and applications from one to four chapters This book presents the fundamentals of computational fluid mechanics for the novice user It provides a thorough yet user friendly introduction to the governing equations and boundary conditions of viscous fluid flows turbulence and its modelling and the finite volume method of solving flow problems on computers Numerical Methods in Fluid Mechanics: Proceedings of the International Symposium on Computational Fluid Dynamics Kōichi Ōshima,1986 **AIChE Symposium Series** American Institute of Chemical Engineers,2000 Introduction to Computational Fluid Dynamics Anil W. Date,2005-08-08 Introduction to Computational Fluid Dynamics is a textbook for advanced undergraduate and first year graduate students in mechanical aerospace and chemical engineering The book emphasizes understanding CFD through physical principles and examples The author follows a consistent philosophy of control volume formulation of the fundamental laws of fluid motion and energy transfer and introduces a novel notion of smoothing pressure correction for solution of flow equations on collocated grids within the framework of the well known SIMPLE algorithm The subject matter is developed by considering pure conduction diffusion convective transport in 2 dimensional boundary layers and in fully elliptic flow situations and phase change problems in succession The book includes chapters on discretization of equations for transport of mass momentum and energy on Cartesian structured curvilinear and unstructured meshes solution of discretised equations numerical grid generation and convergence enhancement Practising engineers will find this particularly useful for reference and for continuing education

An Introduction to Computational Fluid Mechanics by Example Sedat Biringen,Chuen-Yen Chow,2011-03-21 This new book builds on the original classic textbook entitled An Introduction to Computational Fluid Mechanics by C Y Chow which was originally published in 1979 In the decades that have passed since this book was published the field of computational fluid dynamics has seen a number of changes in both the sophistication of the algorithms used but also advances in the computer hardware and software available This new book incorporates the latest algorithms in the solution techniques and supports this by using numerous examples of applications to a broad range of industries from mechanical and aerospace disciplines to civil and the biosciences The computer programs are developed and available in MATLAB In addition the core text provides up to date solution methods for the Navier Stokes equations including fractional step time advancement and pseudo spectral methods The computer codes at the following website www wiley com go biringen *Metallurgical Transactions* ,1993 An Introduction to Computational Fluid Mechanics Chuen-Yen Chow,1983 **Advances of Computational Mechanics in Australia** Yuan Tong Gu,Hong Guan,Emilie Sauret,Suvash Saha,Hai Fei Zhan,Rodney Persky,2016-07-25 Selected peer reviewed papers from the 2nd Australasian Conference on Computational Mechanics ACCM2015 November 30 December 1 2015 Brisbane Australia **Annual Report** India. Department of Science and

Technology,2006 **Engineering Fluid Mechanics** P. A. Aswatha Narayana,K. N. Seetharamu,2005 Engineering Fluid Mechanics discusses applications of Bernoulli s equation momentum theorem turbomachines and dimensional analysis discusses mechanics of laminar and turbulent flows boundary layers incompressible inviscid flows compressible flows and computational fluid dynamics Introduction to wave hydrodynamics experimental techniques and analysis of experimental uncertainty **Civil Engineering Hydraulics Abstracts** ,1985

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