Online Programs

Master of Technology (M.Tech)

in

Computational Fluid-Thermal Sciences (CFTS)

and / or

P. G. Diploma in Computational Fluid-Thermal Sciences (CFTS)

Visvesvaraya National Institute of Technology (VNIT)

South Ambazari Road, Nagpur,

Maharashtra. Pin 440010 (India)

Introduction

M.Tech in Computational Fluid-Thermal Sciences is a two-year postgraduate program designed specifically for working professionals from the industry and anyone who want to advance their career in the field of fluid dynamics and heat transfer. The program is aimed at providing students with the necessary skills and knowledge to apply computational methods and techniques to solve complex engineering problems related to fluid dynamics and heat transfer.

The program is designed to be flexible and accessible to working professionals, with classes scheduled on weekends and evenings. The curriculum includes courses in advanced fluid dynamics and heat transfer, computational methods in fluid dynamics, analysis of fluid flow and heat transfer with OpenFOAM, and advanced numerical methods for fluid flow and heat transfer.

In addition, the program covers topics such as data analytic for engineering applications and machine learning and artificial intelligence in engineering. These courses provide students with the necessary skills to apply modern computational methods and tools to solve complex engineering problems.

The program also includes courses in turbulence modeling and simulation, and multi-physics modeling and simulation, which are essential for understanding complex physical phenomena in fluid-thermal sciences. The program is designed to help students develop the necessary skills to apply computational methods and techniques to real-world problems.

Overall, M. Tech. in Computational Fluid-Thermal Sciences is an ideal program for anyone who want to advance their career in fluid dynamics and heat transfer, and are interested in using computational methods to solve challenging engineering problems. The program equips students with the skills and knowledge needed to succeed in their industry and provides a strong foundation for further research and development in the field.

Eligibility

Candidates must have completed a bachelor's degree in engineering or a related field from a recognized university. The degree must be in a relevant discipline, such as mechanical engineering, aerospace engineering, chemical engineering, or civil engineering.

Duration and Structure

The program is designed to be flexible, allowing candidates to complete the course within a duration of 2-4 years, based on their individual needs and circumstances. Candidates have the option to choose between two tracks:

a) ***M.Tech Program (2-4 years):*** This is designed for candidates who aim to deepen their understanding of computational fluid-thermal sciences by undertaking a research project in addition to completing the required coursework. The program includes a comprehensive set of courses and projects covering both fundamental and advanced concepts. This option provides an opportunity for students to develop independent research skills and to contribute to the advancement of knowledge in the field. The research project can be completed within a duration of 1-2 years, following the coursework. Upon completion, the student will receive an M.Tech degree. Minimum credits requirement will be 52 credits.

b) ***P. G. Diploma Program (1-2 years):*** This is designed for individuals who wish to deepen their knowledge and expertise in fluid dynamics and heat transfer, without taking on a research project. This program consists of a series of courses and projects that cover the essential and advanced concepts in computational fluid-thermal sciences. Upon completion of this option, students will receive a PG diploma certificate as recognition of their academic achievements. Minimum credits requirement will be 40 credits.

Candidates who choose the M.Tech option will work closely with a faculty advisor from VNIT to develop a research project that aligns with their interests. During the thesis work it is mandatory to visit the VNIT for at list one-week time. The project will culminate in a thesis that demonstrates the candidate's ability to conduct original research and make a significant contribution to the field by writing conference and research paper.

Program Highlights:

- Online Delivery: The program is offered in an online format, allowing for flexible and convenient learning from anywhere.
- No GATE Score Required: Applicants are not required to have a GATE score to be eligible for admission.
- Flexible Learning Options: The program offers flexibility in terms of duration, allowing students to choose between a 1-2 year P.G. Diploma program or a 2-4 year M.Tech program based on their preferences and goals.
- Experienced Faculty: The courses are taught by highly experienced faculty members who possess expertise in the field of computational fluid-thermal sciences.
- Industry-Relevant Curriculum: The curriculum is designed to align with the latest industry trends and demands, ensuring that students acquire skills that are directly applicable in the field.

- Practical Hands-On Experience: Students will have opportunities to gain practical experience through hands-on projects and simulations, enabling them to apply their knowledge to real-world scenarios.
- Thesis Completion: M.Tech students will have the opportunity to complete a one-year thesis project, allowing for in-depth research and exploration in their chosen area of interest.
- VNIT Degree: Upon successful completion of the program, students will be awarded a degree from VNIT, a prestigious institution known for its excellence in engineering education.
- Placement Support: The program provides placement support, assisting students in exploring job opportunities and connecting with potential employers in the industry.
- Alumni Benefits: Students become part of the VNIT alumni network, which offers a range of benefits, including networking opportunities and access to career development resources.
- Earn Degree Without Leaving Your Job: The online format of the program enables working professionals to pursue their degree while continuing their employment.
- Annual Visit to VNIT: Students are required to visit VNIT once a year for academic and program-related activities.

Target Audience:

- B.Tech./BE/BS Graduates in Mechanical, Aerospace, Chemical, or Civil Engineering
- Working Professionals seeking to enhance their knowledge and skills in computational fluid-thermal sciences
- Individuals interested in pursuing a career transition into the field of computational fluid-thermal sciences

Scheme of for M.Tech in CFTS

Sr. No	DC/DE	Course Code	Course Title	Credit (L-T-P-credit)
DC Course				
1.	DC	MEL5XX	Advanced Fluid dynamics and Heat Transfer	3-1-0-4
2.	DC	MEL5XX	Computational Methods in Fluid Dynamics	3-0-0-3
3.	DC	MEL5XX	Analysis of Fluid flow and Heat transfer with OpenFOAM	2-2-0-4
4.	DC	MEL5XX	Computational Physics with Python	3-0-0-3
5.	DC	MEL5XX	Advanced Numerical Methods for Fluid flow and Heat Transfer	3-1-0-4
6.	DC	MEL5XX	Advanced simulations and programming with OpenFOAM	1-2-0-3
7.	DC	MEL5XX	Multi-phase flow	3-0-0-3
8.	DC	MEP5XX	Lab: Computational Methods in Fluid Dynamics	0-0-2-1
9.	DC	MEP5XX	Lab: Analysis of Fluid flow and Heat transfer with OpenFOAM	0-0-2-1
10.	DC	MEP5XX	Lab: Advanced simulations and programming with OpenFOAM	0-0-2-1
11.	DC	MEP5XX	Phase-I project	0-0-0-6
12.	DC	MEP5XX	Phase-II project	0-0-0-6
			Total Credit	**39**
DE Course				
1.	DE	MEL5XX	Data Analytics for Engineering Applications	3-0-0-3
2.	DE	MEL5XX	Convective heat transfer	3-0-0-3
3.	DE	MEL5XX	Boundary layer theory	3-0-0-3

4.	DE	MEL5XX	Machine Learning and Artificial Intelligence in Engineering	3-1-0-4
5.	DE	MEL5XX	Engineering Optimization	3-0-0-3
6.	DE	MEL5XX	Finite Element Method	3-0-0-3
7.	DE	MEP5XX	Mini Project	0-0-0-3
8.	DE	MEL5XX	Turbulence Modeling and Simulation	3-0-0-3
Minimum Credits required 52. Kindly select the remaining credits from the above elective courses.				

Scheme of for P.G. Diploma in CFTS

Sr. No	DC/DE	Course Code	Course Title	Credit (L-T-P-credit)
DC Course				
1.	DC	MEL5XX	Advanced Fluid dynamics and Heat Transfer	3-1-0-4
2.	DC	MEL5XX	Computational Methods in Fluid Dynamics	3-0-0-3
3.	DC	MEL5XX	Analysis of Fluid flow and Heat transfer with OpenFOAM	2-2-0-4
4.	DC	MEL5XX	Computational Physics with Python	3-0-0-3
5.	DC	MEL5XX	Advanced Numerical Methods for Fluid flow and Heat Transfer	3-1-0-4
6.	DC	MEL5XX	Advanced simulations and programming with OpenFOAM	1-2-0-3
7.	DC	MEL5XX	Multi-phase flow	3-0-0-3
8.	DC	MEP5XX	Lab: Computational Methods in Fluid Dynamics	0-0-2-1
9.	DC	MEP5XX	Lab: Analysis of Fluid flow and Heat transfer with OpenFOAM	0-0-2-1
10.	DC	MEP5XX	Lab: Advanced simulations and programming with OpenFOAM	0-0-2-1
			Total Credit	**27**
DE Course				
1.	DE	MEL5XX	Data Analytics for Engineering Applications	3-0-0-3
2.	DE	MEL5XX	Convective heat transfer	3-0-0-3
3.	DE	MEL5XX	Boundary layer theory	3-0-0-3
4.	DE	MEL5XX	Machine Learning and Artificial Intelligence in Engineering	3-1-0-4

5.	DE	MEL5XX	Engineering Optimization	3-0-0-3
6.	DE	MEL5XX	Finite Element Method	3-0-0-3
7.	DE	MEL5XX	Turbulence Modeling and Simulation	3-0-0-3
8.	DE	MEP5XX	Mini Project	0-0-0-3
Minimum Credits required 40. Kindly select the remaining credits from the above elective courses.				

- Each Theory credits = 1 Hrs. Tutorial credits = 1 Hrs., and Lab Credits = 2 Hrs.

Fee Structure:

	Fee Structure
M.Tech in CFTS (52 Credits)	Admission Fee (one time) Rs. 15,000 + Rs 6,000/- per credit. Total cost = Rs. 3,27,000/- + GST 18%
P. G. Diploma in CFTS (40 Credits)	Admission Fee (one time) Rs. 15,000 + Rs 6,000/- per credit. Total cost = Rs. 2,55,000/- + GST 18 %

List of faculties:

1. Dr. Trushar B. Gohil, Associate Professor, Dept. Mechanical, VNIT.
2. Dr. (Mrs.) S.A. Raut, Associate Professor, Dept. CS and Engg, VNIT
3. Dr. G. Naga Raju, Associate Professor, Dept. Mathematics, VNIT
4. Dr. Rahul T., Assistant Professor, Dept. Mechanical, VNIT.
5. Dr. Rajendra Soni, Assistant Professor, Dept. Mechanical, VNIT.
6. Dr. Gaurav T., Assistant Professor, Dept. Mechanical, VNIT.

Coordinator:

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Course syllabus

Advanced Fluid dynamics and Heat Transfer

Course Name: MEL5XX - Advanced Fluid dynamics and Heat Transfer

Offered in: Odd Semester

Scheme and Credit: [(3-1-0); Credits: 4]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Develop a deep understanding of the fundamental concepts in fluid dynamics and heat transfer, including Navier-Stokes equations, energy equations, and heat transfer mechanisms.
2. Explore the theoretical and computational aspects of fluid dynamics, including laminar and turbulent flows, and boundary layer theory.
3. Understand the principles of experimental fluid dynamics, including data acquisition and analysis techniques, PIV, LDA, and hot wire anemometry, and heat transfer measurement techniques.
4. Develop an understanding of the applications of fluid dynamics and heat transfer in various engineering systems, including aerospace, chemical, mechanical, and civil engineering.
5. Explore advanced topics in fluid dynamics and heat transfer, such as Microfluidics and nanofluidics, non-Newtonian fluid mechanics, and biofluid mechanics.
6. Apply the concepts and methods learned in the course to solve complex engineering problems related to fluid dynamics and heat transfer.

Syllabus:

Module 1: Introduction to Fluid Dynamics and Heat Transfer: Review of basic fluid mechanics concepts, Thermodynamic properties and energy equations, Heat transfer mechanisms

Module 2: Fundamentals of Fluid Dynamics: Navier-Stokes equations, Exact and approximate solutions for laminar flows, Boundary layer theory

Module 3: Fundamentals of Heat Transfer: Conduction in solids and fluids, Convection in fluids Radiation heat transfer, Analytical and numerical solutions for heat transfer problems

Module 4: Advanced Topics in Fluid Dynamics and Heat Transfer: Flow instability and transition to turbulence, similarity solutions, Applications of fluid dynamics and heat transfer in engineering systems

Module 5: Experimental Methods in Fluid Dynamics and Heat Transfer: Fundamentals of experimental fluid dynamics, Data acquisition and analysis techniques, PIV, LDA, and hot wire anemometry, Heat transfer measurement techniques, Applications of experimental methods in engineering systems

Module 6: Special Topics in Fluid Dynamics and Heat Transfer: Microfluidics and nanofluidics, Non-Newtonian fluid mechanics, Biofluid mechanics and medical applications

Reference Books and materials:

1. Fluid Mechanics: Fundamentals and Applications (4th edition, SIE) Paperback – 28 May 2019 by John. M. Cimbala Yunus A. Cengel (Author)
2. Heat and Mass Transfer: Fundamentals and Applications (SIE) Paperback – 1 July 2017 by Yunus A Cengel; Afshin J. Ghajar (Author)
3. Various research article

Computational Methods in Fluid Dynamics

Course Name: MEL5XX - Computational Methods in Fluid Dynamics

Offered in: Odd Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Develop an understanding of the fundamentals of numerical analysis and discretization methods for partial differential equations.
2. Learn the basics of finite difference method and its application to fluid dynamics problems.
3. Understand the principles of the finite volume method and its application to control volume discretization and conservation laws.
4. Learn the principles of stability and accuracy of numerical methods for fluid dynamics and understand the principles of error analysis.
5. Develop an understanding of the importance of mesh generation and the types of grids used in fluid dynamics simulations.
6. Acquire proficiency in using computational tools and software packages for fluid dynamics simulations.
7. Develop an understanding of the applications of numerical methods in fluid dynamics to solve real-world engineering problems.

Syllabus:

Module 1: Introduction to CFD: Overview of CFD and its applications, Governing equations of fluid dynamics, Discretization methods for CFD, Mathematical nature of PDEs and flow equations, Types of grids used in CFD, CFD software packages

Module 2: Finite Difference Method in CFD: Introduction to finite difference method, Discretization of partial differential equations, Explicit and implicit schemes, Solution of hyperbolic equations using finite difference method Upwind and TVD schemes, Solution of elliptic and parabolic equations using finite difference method

Module 3: Finite Volume Method in CFD: Introduction to finite volume method, Control volume discretization and conservation laws, Implicit and explicit time integration, Solution of hyperbolic, elliptic, and parabolic equations using finite volume method

Module 4: Introduction to Numerical Analysis: Fundamentals of numerical analysis, Error analysis and accuracy of numerical methods, Stability analysis and numerical diffusion.

Module 5: Grid Generation and Post-Processing in CFD: Introduction to grid generation and post-processing in CFD, Basics of structured and unstructured grids, Introduction to mesh quality metrics, Pre-processing of grids: visualization, cleaning, and refinement, Introduction to post-processing of CFD data, Data visualization and analysis tools, Common post-processing tasks: contour plots, velocity vector plots, streamline plots, Validation and verification of CFD simulations using post-processing tools, Advanced post-processing techniques: turbulence statistics, flow visualization, and animation

Module 6: Applications of Numerical Methods in Fluid Dynamics: Computational Fluid Dynamics (CFD) software packages, Modeling of laminar and turbulent flows, Boundary layer analysis and turbulence modeling, Heat transfer analysis using numerical methods, Industrial applications of numerical methods in fluid dynamics

Reference Books and materials:

1. Introduction to Computational Fluid Dynamics: Development, Application and Analysis by Atul Sharma (Author)
2. Introduction to Computational Fluid Dynamics, An: The Finite Volume Method by H. Versteeg (Author), W. Malalasekera (Author)
3. Computational Fluid Mechanics and Heat Transfer (Computational and Physical Processes in Mechanics and Thermal Sciences) by John C. Tannehill (Author), Richard H. Pletcher (Author)

Analysis of Fluid flow and Heat transfer with OpenFOAM

Course Name: MEL5XX- Analysis of Fluid flow and Heat transfer with OpenFOAM

Offered in: Odd Semester

Scheme and Credit: [(2-2-0); Credits: 4]

Course Assessment Method: End Semester exam (40%), assessment through assignments, seminar, project, term-paper etc.

Course Objectives/outcomes:

1. Students will be able to solve steady-state and transient fluid dynamics and heat transfer problems using OpenFOAM.
2. Students will be able to generate and refine meshes for fluid dynamics and heat transfer simulations using OpenFOAM.
3. Students will be able to use OpenFOAM utilities for pre-processing and post-processing of simulation results.
4. Students will be able to apply fluid dynamics and heat transfer concepts and simulation techniques to real-world engineering problems.
5. Students will be able to extend and customize OpenFOAM functionality to solve complex engineering problems.
6. Students will be able to communicate effectively about fluid dynamics and heat transfer simulations using OpenFOAM, both orally and in writing.
7. Students will be able to work effectively in teams to solve engineering problems using OpenFOAM.

Syllabus:

Module 1: Introduction to OpenFOAM: Overview of OpenFOAM and its capabilities, Installation and setup of OpenFOAM, Basic case structure and file organization in OpenFOAM, Use of OpenFOAM utilities for pre-processing and post-processing,

Module 2: Fundamentals of Fluid Flow and Heat Transfer: Governing equations of fluid dynamics and heat transfer, Finite volume method and discretization of equations, Boundary conditions and initial conditions, Turbulence modeling and its applications in OpenFOAM,

Module 3: Steady-state Flow Simulation with OpenFOAM: Setting up and running a steady-state simulation, Use of boundary conditions and initial conditions, Mesh generation and refinement techniques, Post-processing of steady-state flow data

Module 4: Transient Flow Simulation with OpenFOAM: Setting up and running a transient simulation, Use of boundary conditions and initial conditions, Mesh generation and refinement techniques, Post-processing of transient flow data.

Module 5: Heat Transfer Analysis with OpenFOAM: Introduction to heat transfer modeling, Solution of conduction and convection problems using OpenFOAM, Use of heat transfer boundary conditions, Post-processing of heat transfer data.

Module 6: Advanced Topics in OpenFOAM: Solution of multiphase flow problems using OpenFOAM, Solution of compressible flow problems using OpenFOAM, Parallel computing and high-performance computing in OpenFOAM, Customizing and extending OpenFOAM functionality

Reference Books and materials:

1. "The OpenFOAM User Guide" by OpenFOAM Foundation
2. "Computational Fluid Dynamics with OpenFOAM" by S. V. Patankar and S. C. Sharma
3. "Introduction to Computational Fluid Dynamics: Development, Application and Analysis" by E. H. Hirsch
4. "An Introduction to Computational Fluid Dynamics: The Finite Volume Method" by H. K. Versteeg and W. Malalasekera

Computational Physics with Python

Course Name: MEL5XX - Computational Physics with Python

Offered in: Odd Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Gain a good understanding of Python programming and its applications in computational physics.
2. Learn numerical methods commonly used in computational physics, such as root-finding algorithms, interpolation, and numerical integration techniques.
3. Gain practical experience in implementing numerical methods in Python programming language.
4. Learn Monte Carlo simulation techniques and their applications in computational physics.
5. Understand the basics of machine learning and its applications in physics, and develop skills in implementing machine learning algorithms in Python.
6. Learn to use Python libraries and tools commonly used in computational physics, such as NumPy, SciPy, Matplotlib, and scikit-learn.
7. Develop skills in visualizing and analyzing physics data using Python programming and numerical methods software and tools.
8. Gain practical experience in applying Python programming and numerical methods to solve real-world physics problems.

Syllabus:

Module 1: Introduction to Python Programming: Overview of Python and its applications in computational physics, Basic data types, operators, and control structures in Python, Functions, modules, and packages in Python.

Module 2: Numerical Methods in Physics: Introduction to numerical methods and their applications in physics, Root-finding algorithms, such as the bisection method and Newton's method, Interpolation and curve fitting techniques, Numerical integration techniques, such as the trapezoidal rule and Simpson's rule.

Module 3: Solving Ordinary Differential Equations: Introduction to ordinary differential equations (ODEs) and their applications in physics, Numerical methods for solving ODEs, such as the Euler method and the Runge-Kutta methods, Applications of ODEs in physics, such as projectile motion and simple harmonic motion,

Module 4: Monte Carlo Methods in Physics: Introduction to Monte Carlo methods and their applications in physics, Monte Carlo integration techniques, Applications of Monte Carlo methods in physics, such as statistical mechanics and particle physics,

Module 5: Case Studies and Applications: Application of Python programming and numerical methods to real-world physics problems, such as modeling the behavior of complex systems and simulating physical phenomena, Case studies and examples of Python and numerical methods applications in various physics fields, such as mechanics, electromagnetism, and thermodynamics

Reference Books and materials:

1. Computational Physics by Mark Newman (author)
2. A Primer on Scientific Programming with Python (Texts in Computational Science and Engineering) by Hans Petter Langtangen (Author)

Data Analytics for Engineering Applications

Course Name: MEL5XX - Data Analytics for Engineering Applications

Offered in: Odd/Even Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Understand the fundamentals of data analytics and its applications in engineering.
2. Learn techniques for cleaning, filtering, and preprocessing data.
3. Gain proficiency in exploratory data analysis techniques, including statistical measures and data visualization.
4. Develop skills in optimization techniques and algorithms, including linear and nonlinear programming, gradient-based optimization, and evolutionary algorithms.
5. Gain proficiency in simulation software and techniques, such as Monte Carlo simulation and discrete event simulation.
6. Develop skills in applying data analytics techniques to real-world engineering problems, such as manufacturing process optimization and predictive maintenance.
7. Develop skills in applying data analytics techniques to various engineering fields, such as mechanical engineering, electrical engineering, and civil engineering.

Syllabus:

Module 1: Introduction to Data Analytics: Overview of data analytics and its applications in engineering, Key concepts in data analytics, including data types, data structures, and data sources Introduction to data analysis software and tools, such as Python and R,

Module 2: Data Preprocessing: Techniques for cleaning and filtering data, such as data normalization and outlier detection, Strategies for handling missing data, such as imputation and deletion, Data integration and transformation techniques, such as merging and pivoting.

Module 3: Exploratory Data Analysis: Statistical measures and data visualization techniques for exploring and summarizing data, such as histograms, scatterplots, and box plots, Data distribution analysis and correlation analysis, Techniques for dimensionality reduction, such as principal component analysis (PCA).

Module 4: Optimization and Simulation: Introduction to optimization techniques and algorithms

Applications of optimization in engineering, such as parameter tuning and system design Introduction to simulation software and techniques, such as Monte Carlo simulation and discrete event simulation.

Module 5: Case Studies and Applications: Application of data analytics techniques to real-world engineering problems, such as manufacturing process optimization and predictive maintenance, Case studies and examples of data analytics applications in various engineering fields, such as mechanical engineering, electrical engineering, and civil engineering

Reference Books and materials:

1. Data Analysis for Scientists and Engineers by Edward L. Robinson (Author)
2. Data Analytics: Concepts, Techniques, and Applications by Mohiuddin Ahmed (Editor), Al- Sakib Khan Pathan (Editor)
3. Reference papers

Advanced Numerical Methods for Fluid flow and Heat Transfer

Course Name: MEL5XX - Advanced Numerical Methods for Fluid flow and Heat Transfer

Offered in: Even Semester

Scheme and Credit: [(3-1-0); Credits: 4]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Ability to apply numerical methods to fluid flow and heat transfer problems in industry.
2. Understanding of different numerical algorithms and their implementation in CFD simulations.
3. Knowledge of different types of grids and grid generation techniques.
4. Ability to model multiphase flows and understand their applications in engineering.
5. Ability to model one-dimensional heat transfer problems.
6. Knowledge of commercial CFD software and their applications in industry.
7. Ability to use software and tools to solve practical problems related to fluid flow and heat transfer.

Syllabus:

Module 1: Governing Equations and Numerical Methods: Review of governing equations in fluid dynamics, Introduction to numerical methods, including finite volume and finite difference methods Accuracy and stability analysis of numerical methods, Advanced numerical techniques, including high-order methods and adaptive mesh refinement.

Module 2: Numerical Algorithms: Overview of numerical algorithms commonly used in fluid flow and heat transfer, including SIMPLE, MAC, SMAC, PISO, and PIMPLE, Discretization and implementation of these numerical algorithms. Staggered grid and collocated grid formulations.

Module 3: Grid Generation and Algorithms: Overview of different types of grids, including structured, unstructured, and hybrid grids, Grid generation techniques, including structured, unstructured, and hybrid grid generation

Module 4: Multiphase Flows: Introduction to multiphase flows and their applications in engineering, Dispersed multiphase flows: Euler-Lagrange and Euler-Euler methods, Continuous multiphase flows: volume of fluid and level set methods, Applications of multiphase flows in engineering, including fuel spray modeling and bubbly flows

Module 5: One-Dimensional Modeling of Heat Transfer: Introduction to one-dimensional modeling of heat transfer, Conduction heat transfer in fins and other geometries, Modeling of electrical circuits with heat transfer, Applications of one-dimensional heat transfer modeling in engineering.

Module 6: Industry Applications: Application of CFD in industry, including aerospace, automotive, and energy sectors, Overview of commercial CFD software, including ANSYS Fluent and COMSOL Multiphysics, Case studies of CFD simulations in engineering design and optimization.

Reference Books and materials:

1. Numerical Heat Transfer and Fluid Flow by PATANKAR (Author)
2. Introduction to Computational Fluid Dynamics, An: The Finite Volume Method by H. Versteeg (Author), W. Malalasekera (Author)
3. Reference papers

Turbulence Modeling and Simulation

Course Name: MEL5XX- Turbulence Modeling and Simulation

Offered in: odd/Even Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Students will be able to understand the basic concepts of turbulence and its relevance to fluid flow and heat transfer in industry.
2. Students will have a strong understanding of turbulence modeling and simulation techniques, including RANS models, LES, and DNS.
3. Students will be able to evaluate different turbulence models and select the appropriate model for a given application.
4. Students will understand the limitations of wall modeling and be able to select appropriate wall models for their simulations.
5. Students will be able to use turbulence simulation and analysis tools to analyze and optimize their simulations.

Syllabus:

Module 1: Introduction to Turbulence: Introduction to turbulence: definitions and concepts, Reynolds-averaged Navier-Stokes (RANS) equations and turbulence models, Direct numerical simulation (DNS) and large eddy simulation (LES), Experimental methods for studying turbulence

Module 2: RANS Models: Reynolds stress transport models (RSTM), K-epsilon models, K-omega models, Algebraic stress models, Comparison of RANS models,

Module 3: LES and DNS: Overview of large eddy simulation (LES), Subgrid-scale modeling in LES, Overview of direct numerical simulation (DNS), DNS for turbulent flows

Module 4: Wall Modeling: Wall functions and their limitations, Hybrid Reynolds-averaged Navier-Stokes/large eddy simulation (RANS/LES) models, Detached eddy simulation (DES), Wall-resolving LES

Module 5: Modeling Complex Turbulent Flows: Turbulent flows with heat transfer, Turbulent multiphase flows, Turbulent combustion, Turbulent flows in complex geometries, Applications of turbulence modeling in industry

Module 6: Turbulence Simulation and Analysis Tools: Overview of turbulence simulation and analysis software tools, Post-processing and analysis of turbulence simulation data, Turbulence simulation optimization techniques

Module 7: Turbulence Control *and* Optimization: Introduction to turbulence control and optimization, Active and passive flow control techniques for turbulence reduction, Flow control optimization using turbulence models, Applications of turbulence control and optimization in industry

Reference Books and materials:

1. A First Course in Turbulence (The MIT Press) by Henk Tennekes (Author), John L. Lumley (Author)
2. Turbulent Flows by Pope Stephen B. (Author)
3. Large Eddy Simulation for Incompressible Flows: An Introduction (Scientific Computation) by Charles Meneveau (Foreword), P. Sagaut (Author)

Machine Learning and Artificial Intelligence in Engineering

Course Name: MEL5XX - Machine Learning and Artificial Intelligence in Engineering

Offered in: odd/Even Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Students will be able to identify engineering problems that can be solved using Machine Learning and Artificial Intelligence algorithms.
2. Students will be able to apply Machine Learning and Artificial Intelligence algorithms to solve engineering problems.
3. Students will be proficient in using Python libraries for data analysis and modeling in engineering applications.
4. Students will have a deep understanding of the different types of Machine Learning and Artificial Intelligence algorithms and their applications in engineering.
5. Students will have the skills to develop control and optimization strategies for engineering systems.

Syllabus:

Module 1: Introduction to Machine Learning and Artificial Intelligence: Overview of Machine Learning and Artificial Intelligence in engineering, Supervised, unsupervised, and reinforcement learning, Applications of Machine Learning and Artificial Intelligence in engineering, Introduction to Python and relevant libraries (NumPy, Pandas, Scikit-learn)

Module 2: Regression and Classification: Linear regression and regularization, Logistic regression and support vector machines, Decision trees and random forests, Ensemble learning and boosting techniques.

Module 3: Unsupervised Learning: Principal component analysis (PCA), k-means clustering and hierarchical clustering, Dimensionality reduction techniques, Anomaly detection

Module 4: Neural Networks: Introduction to neural networks and deep learning, Feedforward neural networks and backpropagation, Convolutional neural networks (CNNs), Recurrent neural networks (RNNs).

Module 5: Process Control and Optimization: Control systems and feedback loops, Model-based and model-free control, Optimization techniques (e.g. linear and nonlinear programming, evolutionary algorithms), Reinforcement learning for process control and optimization,

Module 6: Time-Series Analysis and Forecasting: Introduction to time-series analysis and forecasting, Time-series decomposition and visualization, Auto-regressive models (AR, ARMA, ARIMA), Long Short-Term Memory (LSTM) networks for time-series forecasting.

Module 7: Applications of Machine Learning and Artificial Intelligence in Engineering: Predictive maintenance and condition monitoring, Quality control and anomaly detection, Design optimization and product development, Robotics and automation

Reference Books and materials:

1. Deep Learning (MIT press, Cambridge, 2016) by Goodfellow, Y. Bengio, A. Courville,

2. Artificial Intelligence A Modern Approach (4th Edition) (Pearson Series in Artifical Intelligence, 2021) by Stuart Russell, Peter Norvig,

3. Deep Learning with Python (Manning Publications Co, 2017) by Francois Chollet.

4. Reference Papers

Advanced simulations and programming with OpenFOAM

Course Name: MEL5XX - Advanced simulations and programming with OpenFOAM

Offered in: Even Semester

Scheme and Credit: [(1-2-0); Credits: 3]

Course Assessment Method: End Semester exam (40%), assessment through assignments, seminar, project, term-paper etc.

Course Objectives/outcomes:

1. Ability to use OpenFOAM for advanced simulation techniques, including multiphase flows, compressible flows, and combustion
2. Ability to customize boundary conditions in OpenFOAM for specific industrial applications
3. Ability to develop basic solvers for parabolic, elliptic, and hyperbolic equations in OpenFOAM
4. Ability to customize and extend OpenFOAM solvers and utilities using C++
5. Ability to apply OpenFOAM in real-world engineering design and optimization
6. Ability to develop customized libraries for specific engineering applications

Syllabus:

Module 1: Introduction to OpenFOAM and its Programming Environment: Introduction to OpenFOAM, Overview of OpenFOAM programming environment, Introduction to C++ programming language.

Module 2: Advanced OpenFOAM Simulation Techniques: Review of fluid dynamics equations and numerical methods, Advanced meshing techniques: dynamic meshing, moving mesh, and adaptive mesh refinement, Solution of advanced fluid flow problems, such as multiphase flows, compressible flows, and combustion.

Module 3: Customizing Boundary Conditions in OpenFOAM: Introduction to Boundary Conditions, Types of boundary conditions, Understanding boundary conditions in OpenFOAM, Built-in Boundary Conditions in OpenFOAM, Overview of built-in boundary conditions, How to select and apply built-in boundary conditions, Overview of user-defined boundary conditions, Examples of customizing boundary conditions, Time-dependent boundary conditions, Industrial applications of customized boundary conditions.

Module 4: Developing Basic Solvers in OpenFOAM: Developing a Solver for Parabolic Equations, Developing a Solver for Elliptic Equations, Developing a Solver for Hyperbolic Equations etc.

Module 5: Customizing and Extending OpenFOAM: Introduction to OpenFOAM libraries and their structure, Overview of solvers and utilities in OpenFOAM, Customizing and extending OpenFOAM solvers and utilities using C++.

Module 6: Advanced Topics in Solver Development: Coupling of different solvers for complex problems, Industrial applications of solver development, Case studies of solver development in engineering design and optimization.

Module 7: Applications of OpenFOAM in Industry: Overview of OpenFOAM applications in industry, including aerospace, automotive, and energy sectors, Real-world case studies of OpenFOAM simulations in engineering design and optimization, Introduction to OpenFOAM-based optimization algorithms.

Module 8: Customized Library Development: Introduction to customization and development of OpenFOAM libraries, Turbulence modeling library development, Developing customized libraries for thermophysical properties, Boundary conditions, and numerical schemes, Hands-on experience in developing customized libraries for specific engineering applications.

Reference Books and materials:

1. OpenFOAM User Guide by OpenCFD Ltd.
2. OpenFOAM programming Guide by OpenCFD Ltd.
3. Reference papers

Multi-Phase Flow

Course Name: MEL5XX- Multi-phase flow

Offered in: Even Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Understanding the fundamentals of multi-phase flows and their applications in engineering.
2. Learning about different types of multi-phase flows, including gas-liquid, liquid-liquid, and gas-solid flows.
3. Gaining knowledge about the governing equations for multi-phase flows and their numerical discretization.
4. Learning about different numerical techniques used for multi-phase simulations, such as volume of fluid (VOF), level set, and Eulerian-Eulerian methods.
5. Understanding the modeling of interfacial phenomena, such as surface tension, contact angle, and wetting.
6. Developing the ability to model complex multi-phase flows, such as bubbly flows, particle-laden flows, and boiling flows.
7. Learning about the use of multi-phase simulations for industrial applications, such as chemical process engineering, energy systems, and biomedical engineering.
8. Developing skills in interpreting and analyzing the results of multi-phase simulations for engineering design and optimization.
9. Developing the ability to communicate effectively on multi-phase modeling and simulation concepts, both orally and in writing.

Syllabus:

Module 1: Introduction to Multi-phase Flows: Overview of multi-phase flows and their applications in engineering, Fundamental concepts, terminology and classification of multi-phase flows, Governing equations of multi-phase flows, Mathematical nature of PDEs and flow equations.

Module 2: Dispersed Multi-phase Flows: Euler-Lagrange and Euler-Euler methods, Modeling of droplet and particle dynamics, Collision models and break-up models, Introduction to population balance equations, Overview of Lagrangian tracking, Applications of dispersed multi-phase flows in engineering, including fuel spray modeling and particle-laden flows.

Module 3: Continuous Multi-phase Flows: Volume of fluid and level set methods, Sharp-interface and diffuse-interface modeling, Cavitation modeling, Introduction to mesh-free and meshless methods, Applications of continuous multi-phase flows in engineering, including bubbly flows, free surface flows and solidification.

Module 4: Numerical Methods for Multi-phase Flows: Overview of numerical methods for multi-phase flows, including finite volume and finite element methods, Numerical discretization of multi-phase flow equations, Treatment of interface and boundary conditions, Introduction to numerical challenges, such as convergence, stability, and accuracy, Advanced numerical techniques for multi-phase flows, including high-order methods, adaptive mesh refinement and parallel computing.

Module 5: Turbulence Modeling for Multi-phase Flows: Overview of turbulence modeling for multi-phase flows, Reynolds-averaged Navier-Stokes (RANS) equations for multi-phase flows, Introduction to large-eddy simulation (LES) and direct numerical simulation (DNS) for multi-phase flows, Advanced turbulence models for multi-phase flows, including two-fluid models and interface-capturing models.

Module 6: Applications of Multi-phase Flows in Engineering: Overview of multi-phase flow applications in industry, including chemical, petrochemical, and energy sectors, Case studies of multi-phase flow simulations in engineering design and optimization, Introduction to experimental techniques for multi-phase flows, such as particle image velocimetry (PIV) and laser Doppler anemometry (LDA).

Module 7: Software and Tools for Multi-phase Modeling: Overview of commercial software packages for multi-phase modeling, including ANSYS Fluent and COMSOL Multiphysics, Introduction to open-source software for multi-phase modeling, such as OpenFOAM, Hands-on experience in using software for multi-phase modeling, including set-up, simulation, and post-processing.

Reference Books and materials:

1. Computational Methods for Multiphase Flow by Andrea Prosperetti (Editor), Gretar Tryggvason (Editor)
2. Multiphase Flow Handbook (Mechanical and Aerospace Engineering Series) by Efstathios Michaelides (Editor), Clayton T. Crowe (Editor), John D. Schwarzkopf (Editor)
3. Reference Papers

Convective Heat Transfer

Course Name: MEL5XX- Convective Heat Transfer

Offered in: odd/even Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Develop a fundamental understanding of convective heat transfer, including heat transfer coefficients, boundary layer theory, and turbulence modeling.
2. Gain expertise in analyzing and modeling convective heat transfer in different flow regimes, such as laminar, transitional, and turbulent flows.
3. Understand the physics of convective heat transfer in various applications, such as combustion, high-speed flows, and heat exchangers.
4. Apply the principles and techniques of convective heat transfer to real-world engineering problems, such as thermal management of electronic devices, design of heat exchangers, and optimization of combustion systems.
5. Develop critical thinking skills and problem-solving skills through analysis of case studies and research articles related to convective heat transfer.

Syllabus:

Module 1: Fundamentals of Convective Heat Transfer: Introduction to convective heat transfer, Modes of convective heat transfer (forced, natural, mixed), Governing equations for convective heat transfer, Boundary layer theory, Thermal boundary layer similarity solution, Non-dimensional parameters (Prandtl number, Nusselt number, Reynolds number), Scaling laws and similarity analysis

Module 2: Forced Convection: Basics of forced convection, Hydrodynamic and thermal boundary layers, Flat-plate and circular-tube flows, Turbulent boundary layers and their characteristics, Heat transfer in turbulent flows, Empirical correlations for heat transfer coefficient, Heat transfer enhancement techniques (ribbed surfaces, vortex generators, etc.).

Module 3: Natural Convection: Basics of natural convection, Grashof number and Rayleigh number, Vertical and horizontal plate flows, Enclosure flows, Heat transfer enhancement techniques (thermal buoyancy forces, etc.)

Module 4: Mixed Convection: Basics of mixed convection, Examples of mixed convection flows

Heat transfer in mixed convection flows, Empirical correlations for heat transfer coefficient, ***Module 5: Convection in Combustion:*** Introduction to combustion, Flame structure and flame speed, Premixed and diffusion flames, Combustion in laminar and turbulent flows, Combustion-generated buoyancy forces, Heat transfer in combustion systems

Module 6: Convection in High Speed Flows: Introduction to high-speed flows, Shock waves and their effects on heat transfer, Boundary layer transition and turbulence, Heat transfer in hypersonic flows, Convective heating and thermal protection systems

Module 7: Advanced Topics: Computational Fluid Dynamics (CFD) for convective heat transfer, Heat transfer in complex geometries and flows, Heat transfer in multiphase flows, Heat transfer in porous media, Heat transfer in nanofluids,

Module 8: Applications: Industrial applications of convective heat transfer (aerospace, automotive, power generation, etc.), Case studies of convective heat transfer in engineering design and optimization, Emerging trends and future directions in convective heat transfer research

Reference Books and materials:

1. Convection Heat Transfer by Adrian Bejan
2. Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation by J. Warnatz (Author), Ulrich Maas (Author), Robert W. Dibble (Author)
3. Convective Heat Transfer by LC Burmeister (Author)
4. Research Papers

Engineering Optimization

Course Name: MEL5XX- Engineering Optimization

Offered in: odd/even Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Understand the concepts and principles of engineering optimization.
2. Formulate and solve optimization problems using various techniques and algorithms.
3. Analyze and interpret optimization results for engineering applications.
4. Use optimization software and tools for solving real-world engineering problems.
5. Apply optimization techniques to solve problems in different engineering domains.
6. Develop critical thinking and problem-solving skills in engineering optimization.

Syllabus:

Module 1: Introduction to Optimization: Definition of optimization, Types of optimization problems, Problem formulation and optimization modeling, Optimization algorithms and software

Module 2: Linear Programming: Introduction to linear programming, Formulation of linear programming problems, The simplex algorithm, Sensitivity analysis and duality,

Module 3: Nonlinear Programming: Introduction to nonlinear programming, Formulation of nonlinear programming problems, Unconstrained optimization algorithms, Constrained optimization algorithms: KKT conditions, Lagrange multipliers, and penalty function methods

Module 4: Integer Programming: Introduction to integer programming, Formulation of integer programming problems, Branch and bound algorithm, Cutting plane method

Module 5: Multi-Objective Optimization: Introduction to multi-objective optimization, Formulation of multi-objective optimization problems, Pareto optimality and the concept of the Pareto front, Multi-objective optimization algorithms

Module 6: Optimization Applications in Engineering: Engineering design optimization problems, Optimization in manufacturing processes, Optimization in logistics and transportation, Optimization in energy systems

Module 7: Stochastic Optimization: Introduction to stochastic optimization, Formulation of stochastic optimization problems, Monte Carlo simulation and sampling methods, Stochastic optimization algorithms: simulated annealing, genetic algorithms, and particle swarm optimization

Reference Books and materials:

1. Optimization Concepts and Applications in Engineering by Ashok D. Belegundu (Author), Tirupathi R. Chandrupatla (Author)
2. Evolutionary Optimization Algorithms: Biologocally -Inspired and Population-Based Approaches to Computer Intelligence by D Simon (Author)
3. Multi-Objective Optimization using Evolutionary Algorithms y Kalyanmoy Deb
4. Optimization for Engineering Design: Algorithms and Examples, by Kalyanmoy Deb

Boundary Layer Theory

Course Name: MEL5XX- Boundary Layer Theory

Offered in: even/odd Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. To introduce students to the concepts and principles of boundary layer theory in fluid mechanics
2. To provide students with an understanding of the physics of boundary layer formation, growth and separation, and its applications in various engineering fields
3. To develop the mathematical skills and knowledge required to analyze and solve problems related to boundary layer flows
4. To introduce students to different types of boundary layers, including laminar and turbulent boundary layers, and their characteristics
5. To provide students with an understanding of the limitations and assumptions of boundary layer theory and its applicability in different situations
6. To develop students' ability to communicate effectively about boundary layer theory and its applications in various engineering fields.

Syllabus:

Module 1: Introduction to Boundary Layers: Definition and types of boundary layers, Historical background and significance of boundary layer theory, Reynolds number and scaling laws.

Module 2: Laminar Boundary Layers: Derivation of Navier-Stokes equations for a laminar boundary layer, Similarity solutions for laminar boundary layers, Development of momentum and energy thicknesses, Laminar separation and transition to turbulence

Module 3: Turbulent Boundary Layers: Turbulence characteristics and statistical properties, Reynolds-Averaged Navier-Stokes equations for turbulent flows, Reynolds stresses and eddy viscosity models, Turbulent boundary layer structure and similarity solutions

Module 4: Boundary Layer Control: Boundary layer control mechanisms and devices, Laminar flow control techniques, Turbulent flow control techniques, Optimization of boundary layer control strategies

Module 5: Applications of Boundary Layer Theory: Aerodynamic drag reduction and lift enhancement, Heat transfer enhancement and thermal management, Combustion and chemical reactions in boundary layers, Acoustic and noise control using boundary layers,

Module 6: Advanced Topics in Boundary Layer Theory: Transition prediction and control, High-speed boundary layers and hypersonic flows, Boundary layer instabilities and turbulence modeling, Boundary layer theory in non-Newtonian fluids

Reference Books and materials:

1. Boundary Layer Analysis Paperback by Joseph C. Schetz (Author)
2. Boundary-Layer Theory by Egon Krause (Contributor), Herbert Oertel jr. (Contributor), Hermann Schlichting (Deceased) (Author)
3. Research Papers

Finite Element Method

Course Name: MEL5XX- Finite Element Method

Offered in: odd/even Semester

Scheme and Credit: [(3-0-0); Credits: 3]

Course Assessment Method: Mid Semester Examination (25%), Internal assessment through assignments (35%), End Semester exam (40%).

Course Objectives/outcomes:

1. Understand the basics of finite element method and its applications in engineering problems.
2. Understand the formulation of finite element equations for different types of problems, including solid mechanics, fluid mechanics and heat transfer.
3. Develop finite element codes for solving 1D, 2D, and 3D problems.
4. Analyze and interpret the results of finite element simulations.
5. Develop an understanding of error estimation and convergence analysis in finite element method.
6. Apply finite element method to real-world engineering problems and perform design optimization.

Syllabus:

Module 1: Introduction to Finite Element Method: Historical development of Finite Element Method, Overview of FEM and its applications in engineering, Introduction to variational methods and principle of virtual work, Basic steps in finite element analysis

Module 2: One-Dimensional Finite Element Method: Introduction to one-dimensional problems, Derivation of the governing equation for a bar element, Formulation of the stiffness matrix and load vector, Assembly of the global stiffness matrix and load vector, Solution of the system of equations

Module 3: Two-Dimensional Finite Element Method: Introduction to two-dimensional problems, Derivation of the governing equation for a plate element, Formulation of the stiffness matrix and load vector, Assembly of the global stiffness matrix and load vector, Solution of the system of equations

Module 4: Isoparametric Formulation: Introduction to isoparametric elements, Derivation of the shape functions for isoparametric elements, Formulation of the stiffness matrix and load vector using isoparametric elements, Advantages of isoparametric formulation

Module 5: Dynamic Analysis with FEM: Introduction to dynamic analysis, Derivation of the equations of motion, Formulation of the mass matrix, Solution of the system of equations for transient analysis, Eigenvalue analysis for natural frequencies and mode shapes

Module 6: Nonlinear Finite Element Analysis: Introduction to nonlinear analysis, Nonlinear material behavior, Geometric nonlinearity, Solution techniques for nonlinear analysis

Reference Books and materials:

1. The Finite Element Method: Theory, Implementation, and Applications: 10 (Texts in Computational Science and Engineering) by Mats G. Larson (Author), Fredrik Bengzon (Author)
2. Fundamentals of Finite Element Analysis by Hutton David
3. Reference papers.