Department of Mechanical Engineering,
Amrita School of Engineering
Amritapuri Campus, Kollam, Kerala, India.

Master of Technology (M.Tech)
in
Thermal and Fluids Engineering

Curriculum and Syllabus

Revised on: December 2021
Previous revisions: 2017, 2015, 2011
Preface

As the energy and process sector in India is in a boom, the need of the hour is engineers with strong background in thermal and fluid sciences capable of carrying out conceptual design. The program is aimed at providing sufficient theoretical, computational and experimental knowledge in the thermal and fluid sciences. It also encapsulates simulation and experimental skills applied to IC engines, power plant, aerospace and gas turbines research. The program is designed to equip students to perform design related to linear and nonlinear steady state/ transient heat transfer, steady and unsteady fluid flow, multiphase flows, fluid structure interactions viz., estimation of thermal and pressure loads and coupled field analysis.

The program provides required numerical simulation techniques for design and analysis of equipment like gas turbines and accessories, steam turbines and reactor pipes, heat exchangers, compressors, turbines, pumps, propellers, rotor stator interactions, flow separators, inlet manifolds, volutes, turbo chargers etc. The program include adequate courses for numerical analysis and computer simulation of thermal engineering problems. The course also introduces the student to experimental techniques like flow visualization, combustion diagnostics, particle characterization and other recent imaging techniques adopted in the field of thermal research. As automation is being introduced in various fields of research and industry, new courses covering these topics are also included. Students will be eligible for the post of design/research engineers in industries related thermal and fluid sciences. This program provide excellent background needed to employment in various R&D organizations and also for high quality academic research.
Program Educational Objectives of the M. Tech (Thermal & Fluids Engineering)

PEO1: This program provides a state-of-art academic curriculum that is intended for students from Mechanical Engineering, Aerospace Engineering and Chemical Engineering exposing the students to various subjects related to thermal and fluids engineering and offering the students exactly what is required to master the technical knowledge required.

PEO2: This programme provides a comprehensive educational environment and enables students to gain expertise in various thermo-fluid systems of practical relevance.

PEO3: Expose students to the designed course works and practical thermo-fluid systems, and prepare them to become engineers/designers in industries, researchers in academia and R&D organisations.

Program Outcomes (POs)

PO1: An ability to independently carry out research/investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
CURRICULUM

M.TECH. THERMAL AND FLUIDS ENGINEERING (TFE)

First Semester

<table>
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*Non-credit course

Second Semester

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Credits 11

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Credits 15

Total Credits for M.Tech Program: 68
### Electives (Elective I & II)

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Module-1

Module-2
Vector calculus: Univariate, Multivariate and vector functions, Motion of a particle in space, Differentiation and Taylor’s series expansion of univariate functions, Partial differentiation, chain rule, Gradient of vector function(Jacobian), Gradient of a vectors with respect to a matrix, Gradient of matrices with respect to a matrix, Identities for computing gradients, Back propagation and automatic differentiation, Gradients in deep neural networks, Higher order partial derivatives, Hessian, Taylor’s series expansion of multivariate functions, Vector calculus for physical field problems, Directional derivative and direction of maximum derivative, divergence and curl of vector fields, rotational and irrotational vector fields, Conservative vector fields, Vector integral calculus, line, surface and volume integrals, Stoke's theorem, Green's theorem and Gauss divergence theorem, applications of vector calculus theorems to field problems, Algebra of Cartesian Tensors, Index notation, Isotropic tensors, Invariants of a tensor.

Module-3

Probability: Introduction to Probability concepts, one dimensional and two dimensional Random variables, Jointly Distributed Random Variables, Conditional Distributions, convergence and limit theorems, Bayesian methods of estimation, Chebychev’s Inequality, Parameter Estimation, Hypothesis testing.

TEXTBOOKS / REFERENCES
Course Outcomes

CO1: Capability to understand mathematical notations and solve problems in linear algebra.

CO2: Capability to do gradient evaluations of objective functions in optimization problems.

CO3: Capability to do scalar and vector field operations.

CO4: Capability for solving mathematical equations modelled as differential equations.

CO5: Solve problems in distribution of random variables and parameter estimation.

**21TF601** Advanced Fluid Dynamics

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Module-1


Module-2

Boundary Layer Theory: Laminar Boundary Layer Equation, Two dimensional equations, displacement and momentum thickness, general properties of the boundary layer equations, skin friction. Turbulent Boundary Layer: Two-dimensional equation, Prandtl’s mixing layer Karman’s hypothesis universal velocity distribution, RANS models, flow over a flat plate, skin friction drag. Introduction to hydrodynamic theory of lubrication.

Module-3


**TEXTBOOKS / REFERENCES**

Course Outcomes

CO1: Develop fundamental knowledge in the subject of fluid mechanics
CO2: Capability to analyse fluid flows of different types associated with different engineering situations
CO3: Develop skill to propose solutions to fluid flow problems to cater to industrial needs
CO4: Capability to conduct research activities in the area of fluid mechanics

21TF602 Advanced Heat Transfer

Module-1

Fourier’s law, thermal conductivity of matter, heat diffusion equation for isotropic and anisotropic media, boundary and initial conditions. One-dimensional steady-state conduction through plane wall, cylinder and sphere. Conduction with thermal energy generation, heat transfer from extended surfaces, radial fins and fin optimization; Multidimensional- steady-state heat conduction; Transient conduction – lumped capacitance method and its validity, plane wall and radial systems, semi-infinite solid, anisotropic conduction.

Review of viscous flow: Hydrodynamic and thermal boundary layers, Laminar flow heat transfer to developed and developing flow, laminar forced convection in pipe and ducts with different boundary conditions, external flows.

Module-2

Turbulence modeling, Heat transfer in turbulent boundary layers, Eddy diffusivity of heat and momentum, turbulent flow through circular tubes and parallel plates with heat transfer, analogies between heat and momentum transfer.

Laminar natural convection, natural convection in enclosures, heat transfer correlations. Turbulent natural convection, turbulent heat transfer correlation, Practical applications.

Boiling and condensation heat transfer – correlation and applications. Heat transfer with phase change: Pool boiling, convective boiling, film and drop wise condensation, empirical relations for heat transfer with phase change.
Module-3

Heat Exchangers: Types, classifications, selection, standards, parallel, counter and mixed flow, multiple passes, LMTD, correction factors, effectiveness, NTU methods. Practical problems and examples which covers the modelling of various heat transfer systems drawn from industrial fields such as manufacturing, electronics, consumer products, and energy systems etc.

Radiation heat transfer, blackbody radiation, Plank distribution, Wien’s displacement law, Stefan-Boltzmann law, surface emission, surface absorption, reflection, and transmission, Kirchoff’s law, gray surface; Radiation intensity and its relation to emission, irradiation and radiosity, View factors and Radiation exchange between surfaces. Elements of inverse heat transfer.

TEXTBOOKS / REFERENCES


Course Outcomes

CO1: Deal with the practical situations which involve one or more than one modes of heat transfer
CO2: Deal with transient and multi-dimensional conduction problems
CO3: Analyse the situation including fluid flow and heat transfer
CO4: Deal with the effect of radiation and heat transfer associated with it in practical situations
CO5: Understand the concepts of condensation and boiling
CO6: Design heat exchangers using LMTD and NTU methods

**21TF603** Advanced Engineering Thermodynamics

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Module-1

Module-2

Module-3
Thermodynamics of reactive systems: First and second law analysis of chemical reactions, thermodynamics of combustion, flames, adiabatic flame temperature.
Thermodynamics of irreversible processes: Phenomenological laws, reciprocity relation, applicability of the phenomenological relations, heat flux and entropy production, thermodynamic phenomena, thermoelectric phenomena.

TEXTBOOKS/REFERENCES

Course Outcomes
CO1: Understand and apply the thermodynamic principles to reacting and non-reacting systems.
CO2: Understand the concept of kinetic theory and statistical thermodynamics.
CO3: Analyse the performance of new generation power plant and fuel cell systems.

21TF604 Applied Computational Methods
L T P C
3 0 3 4

Module-1
Numerical solution of nonlinear algebraic equations: false position, secant, Newton-Raphson, Brent's method;
Solution of linear algebraic systems: Rank of a matrix, Vector Space, determinant, inverse, norms and condition number; Gauss elimination, Gauss-Jordan, Jacob Algorithm; Eigenvalues and Eigenvectors - Power and inverse power method, Eigenvalue Problems, Singular Value Decomposition, Proper Orthogonal Decomposition.
Module-2

Solution using iterative methods: Gauss Seidel, SOR (point and line), Conjugate gradient, BiCGStab, GMRES, Solution of systems of nonlinear algebraic equations; Interpolations: Newton, Stirling, Lagrange, Richardson, Quadratic and Cubic splines, Inverse interpolation; Numerical Differentiation; Numerical integration: Higher-Order Newton-Cotes formulas, Romberg integration, multiple integrals. Least Square Regression: Linear Regression, Polynomial Regression, General Linear Regression, Multiple linear regression, Nonlinear Regression;

Module-3


TEXTBOOKS/REFERENCES:


Course Outcomes

CO1: Solution of nonlinear equations.
CO2: Determination of characteristics of matrices
CO3: Find solution of system of equations
CO4: Interpolation of equally and unequally spaced data and inverse
CO5: Numerically integrate and differentiate using data points and functions
CO6: Carryout efficient regression analysis
CO7: Solution of ODEs
CO8: Classification and solution of PDEs
CO9: Application of Finite Difference methods

21TF605 Experimental Methods L T P C
0 0 3 1

EXPERIMENTS

1. a) Pipe friction apparatus b) Reynolds apparatus
2. a) Thermal conductivity of solids  
b) Heat transfer through pin fin
3. a) Notch apparatus  
b) Pelton wheel test rig
4. a) Forced convection heat transfer  
b) Natural convection heat transfer
5. a) Verification of Bernoulli equation  
b) Centrifugal pump test rig
6. a) Parallel & counter flow heat exchanger  
b) Shell and tube heat exchanger
7. a) Meta-centre apparatus  
b) Venturi and orifice meter test rig
8. a) Stephan-Boltzmann apparatus  
b) Emissivity apparatus
9. a) Francis turbine test rig  
b) Hele-Shaw flow apparatus
10. R&AC test rig.

TEXT BOOKS/REFERENCES


Course Outcomes

CO1: Gain confidence and develop physical insight into the fundamental concepts in fluids and thermal engineering
CO2: Identifying sources of errors in experiments and estimate uncertainty
CO3: Understand and utilize curve fitting techniques.

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Module 1


Problem Formulation, Understanding Modelling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes.

Module 2


Module 3

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript.

References, Citation and listing system of documents Intellectual property rights (IPR) - patents-

**TEXTBOOKS/ REFERENCES**


**Course Outcomes**

CO1: To define research, methodology and steps involved in research.

CO2: To learn to define a problem, and research hypothesis. To understand the importance of literature survey, gaps and challenges.

CO3: To learn the basic concepts of research design, sampling, modeling & simulation and understand the importance of citation, H-index, Scopus.

CO4: To learn to write technical report, paper and thesis.

CO5: To know about intellectual property rights, ethics in research and plagiarism.
Module 1
Review of Conservation equations for mass, momentum and energy; Equations in rectangular, cylindrical and spherical coordinate systems; Eulerian and Lagrangian approach, Conservative and non-conservative forms of the equations, rotating co-ordinates.

Classification of system of PDEs: parabolic elliptic and hyperbolic; Boundary and initial conditions;

Numerical Grid Generation: Basic ideas, transformation and mapping, unstructured grid generation, hybrid grids, moving grids, unmatched meshes, CGNS notation for grid and data, mesh-free calculations.

Module 2
Finite Volume Method: Basic methodology, finite volume discretization, approximation of surface and volume integrals, interpolation methods - Central, Upwind, Hybrid, Power Law and QUICK formulations and comparison for convection-diffusion problem;

TVD schemes, Flux limiter functions;

Advanced Finite Volume methods: FV discretization in two and three dimensions, SIMPLE algorithm and flow field calculations, variants of SIMPLE - SIMPLER, SIMPLEC; PISO and PIMPLE algorithms.

Module 3
Turbulence and turbulence modelling, Introduction to turbulence modelling, Reynolds stress, RANS model, one-, two- and multiple equations for turbulence modelling; Reynolds Stress Transport Model; Large Eddy Simulation, Detached Eddy Simulation and Direct Numerical Simulation methods; Illustrative flow computations using CFD codes.

CFD methods for compressible and high-speed flows; reacting flows.


Formulation for fluid-structure interactions: Moving mesh and adaptive mesh, acoustic fluids coupled to structures, Navier-Stokes fluids coupled to structures


Introduction to open source CFD packages and solution to practical problems.
TEXTBOOKS/ REFERENCES


Course outcomes

CO1: Familiarisation with conversation equations in different forms.
CO2: Ability to classify a system of PDEs.
CO3: Generate most appropriate grid for the problem at hand and familiarise with latest standards.
CO4: Apply FVM techniques for diffusion and convection-diffusion problems.
CO5: Usage of higher order numerical schemes for oscillation free solutions.
CO6: Understand and apply different pressure-velocity coupling for incompressible flows.
CO7: Numerical modelling of turbulence and ability to choose the most optimum one for a problem.
CO8: Solution of compressible fluid flows and its applications
CO9: Usage of commercial CFD codes
CO10: Usage of open source CFD codes and its modifications

21TF612 Design & Optimization of Thermal Systems L T P C
3 1 0 4

Module 1

Basic considerations in design, importance of modelling in design, types of models, mathematical modelling, physical modelling and dimensional analysis, methods of numerical simulation, numerical simulation versus real systems.
Acceptable Design of a Thermal System, Modelling of thermal energy systems: heat exchanger, distillation, turbo machinery components, refrigeration systems; one-dimensional flow network development using software, Information flow diagram.
Module 2

Linear programming, Simplex Method, duality theory, sensitivity analysis, integer-programming formulations;
Unconstrained optimization, One-dimensional search, Gradient based methods-steepest descent, Cauchy’s steepest descent method, Newton’s method, conjugate gradient method,
Nonlinear programming: convex set, Lagrange multiplier, gradient methods, necessary and sufficient condition,
Geometric, Linear, and Dynamic Programming and Other Methods for Optimization.
Multivariable Optimization, Karush-Kuhn-Tucker (KKT) conditions; Stochastic optimization: stochastic gradient descent, dynamic programming, Markov Chain Monte Carlo (MCMC) based optimization; Introduction to heuristic search.

Module 3

Non-traditional optimization: Introduction to Genetic algorithm (GA): basics features, principle and robustness of GA, Particle swarm optimization, Simulated Annealing, Artificial Neural Network (ANN), fuzzy logic etc. with single objective function. Computer programming, other evolutionary algorithms. Formulation of engineering problem and solve with Non-traditional optimization
Optimization of Thermal Systems, Practical Aspects in Optimal Design, Application of Lagrange Multipliers to Thermal Systems;
Dynamic behavior: Steady state Simulation, Laplace Transformation, Feedback Control Loops, Stability Analysis, Nonlinearities.
Case studies of optimization in thermal systems problems- Dealing with uncertainty- probabilistic techniques – Trade-offs between capital and energy using Pinch analysis

TEXTBOOKS/ REFERENCES


Course Outcomes

CO1: Understand the concepts and need for optimisation
CO2: Familiarize with the various calculus and search techniques of optimisation problems
CO3: Familiarize with the Non-traditional optimisation techniques
CO4: integrate thermal component models and simulate a thermal system
CO5: perform an economic analysis of a thermal system
CO6: use the computer to solve thermal system models
CO7: communicate thermal system designs both orally and in writing
CO8: apply optimization procedures and design optimized thermal systems
CO9: study the recent developments and practices in energy and thermal systems
CO10: Outline the concept of thermal systems design
CO11: Develop model of thermal systems and its simulation.
CO12: Apply concept of economics to thermal system.

21TF613 Compressible Fluid Flow

Module-1


One dimensional Isentropic Flow: Governing equations, stagnation conditions, critical conditions, maximum discharge velocity, isentropic relations.

Module-2


Expansion Waves: Prandtl-Meyer flow, reflection and interaction of expansion waves, flow over bodies involving shock and expansion waves; Linearized two dimensional subsonic flows; Prandtl-Glaust / Goethert transformation, Linearized supersonic flow; Ackeret's theory.

Variable Area Flow: Equations for variable area flow, operating characteristics of nozzles, convergent-divergent supersonic diffusers, Under-expansion and over-expansion, contour optimization, bell nozzle, new nozzle concepts.

Module-3

Introduction to the method of Characteristics

Adiabatic Flow in a Duct with Friction (Fanno flow): Flow in a constant area duct, friction factor variations, the Fano line. Flow with Heat addition or removal (Reyleigh flow): One-dimensional flow in a constant area duct neglecting viscosity, variable area flow with heat addition.

Introduction to the design of subsonic & supersonic wind tunnels, Introduction to moving shocks and shock tube.

Experimental measurements: Pitot probes, Total temperature probes, Shadowgraph imaging, Schlieren imaging.

TEXTBOOKS/ REFERENCES

Course Outcomes

CO1: Develop fundamental knowledge in the subject of compressible flows
CO2: Development of capability to analyse compressible fluid flows of different types associated with different engineering situations
CO3: Develop skill to propose solutions to compressible flow problems to cater to aeronautical needs
CO4: Academic capability to conduct research activities in the area of compressible flows

21TF614 Project Seminar & Industry familiarization

This seminar forms the pre-runner to the final year project in which students are expected to do a thorough literature survey and formulate a research problem on the broad topic given by the faculty. Students shall extensively study the research already carried out on the seminar topic. They shall bring out the current status of the problem, clearly indicating the shortcomings and gaps in the investigation carried out so far. Students shall prepare a properly formatted seminar report giving all of the above details. They need to present the work carried out at the end of the semester. Credits will be awarded based on the viva-voce during the presentation and the content and organization of the report.

Students shall visit industrial units connected with their curriculum and conduct a detailed study on thermo-fluid systems pertinent to the industry visited and present reports. They are encouraged to solve a practical problem related to the industry.

Course Outcomes

CO1: Identify appropriate journals/conferences related to a topic of research interest and conduct literature review
CO2: Develop awareness of the recent trends in the topic of investigation
CO3: Write technical reports in prescribed formats
CO4: Identify research gaps and formulate valid research problem worthy of publishing in reputed journals
Dynamic similarity and scaling; Types of measurement devices & techniques; Errors in Measurement and its Analysis: Causes and types of experimental errors, systematic and random errors; Uncertainty analysis, computation of overall uncertainty, calibration.

Experiments in Wind Tunnel: Surface pressure distribution on circular cylinder, symmetric and cambered aero-foils-estimation lift and drag, smoke flow visualization. Laminarturbulent transition for various geometries.

Experiments in Water Channel: Visualization of flow over streamline and bluff bodies vortex shedding from bluff bodies (like circular cylinder)-study of vortex streets.

2-D laminar flow over bluff bodies (Hele-Shaw flow)-construction of flow net (velocity potential lines and streamlines). Numerical visualization of flow over bluff bodies using Ansys/Algor Software-comparison of numerical flow patterns with experimental ones.

Performance characteristics of Centrifugal compressor and axial flow fan.


Steady state and transient convective heat transfer.


Experiments in supersonic jet: static pressure distribution in the nozzle wall, estimation of Mach number.

Experiments in pneumatic and hydraulic systems

TEXT BOOKS/REFERENCES


Course Outcomes

CO1: Develop physical insight into the advanced concepts in fluids and thermal engineering
CO2: Design experiments to estimate physical variables involved in fluid flow and heat transfer
CO3: Conduct research studies in fluid flow and heat transfer
Dissertation (stage-1) should be based on the area in which the candidate has undertaken the dissertation work as per the common instructions for all branches of M. Tech. The examination shall consist of the preparation of report consisting of a detailed problem statement, literature review and initial results of the problem. The work has to be presented in front of the examiners consisting of Head of the Department and PG coordinator/Faculty Advisor and other invited faculty members (if any). The candidate has to be in regular contact with his guide and the topic of dissertation must be mutually decided by the guide and student.

**Course Outcomes**

CO1: Identify appropriate methodology to solve a research problem
CO2: Execute their research investigation adopting the chosen methodology and obtain results
CO3: Write a technical report in a prescribed format.

Dissertation (Stage-2) will start in semester IV which is expected to be a continuation of Dissertation-1. In this phase of the project, students are expected to do the remaining part of their works done in stage-1. To particularly note, this phase of the project involves detailed data acquisition and subsequent analysis of the research problem. The dissertation should be presented in standard format as provided by the department/guide. The candidate has to prepare a detailed project report consisting of introduction of the problem, problem statement, literature review, objectives of the work, details of methodology adopted (experimental/numerical/analytical) and results and discussion. The report must bring out the conclusions of the work and future scope for study. The work has to be presented before the panel of examiners consisting of an approved external examiner, internal examiner/guide as decided by the department head and PG coordinator/faculty advisor. The candidate has to be in regular contact with his/her guide throughout the project duration. All the students are expected to publish their works in reputed journals/conferences (Scopus-indexed).

**Course Outcomes**

CO1: Carry out detailed analysis of research data acquired through experimental/numerical/analytical methodologies in the context of the existing literature and draw valid conclusions thereof.
CO2: Write the project report systematically in a prescribed format.
CO3: Write research articles worthy of publishing in reputed journals/conferences (SCI-indexed/Scopus-indexed)
Module-1

Basics equations of Fluid Mechanics, Potential flows, Stream function, Velocity potential, Two-dimensional incompressible flows: Laplace's equation, its solutions, Elementary potential flows, Superposition principle, the combination of elementary potential flows, conformal mapping. Implementation of conformal mapping textbook problems with the help of python/Matlab programming.

Module-2

Boundary layer: Laminar and Turbulent boundary layers: characteristics and factors causing separation, Effect of boundary layer separation on flow over airfoils. Introduction to bluff body aerodynamics: flow over circular cylinders, effect of Reynolds number and geometry, dynamic effects. Vortex shedding: modes and mechanisms, Strouhal number, aerodynamic coefficients, span-wise correlation. Implementing the concepts in real-life aerodynamic problems using CFD simulations or experimental techniques.

Module-3


TEXT BOOKS/REFERENCES


Course Outcomes

CO1: Development of insight into the fundamental concepts and write the equations governing the fluid flow.

CO2: Gaining conceptual understanding of Stream function, velocity potential solutions to Laplace’s equation and to know the conditions under which potential-flow theory hold.
CO3: Skill to use superposition to build simple potential flows and to understand the concept of conformal mapping and its applications.

CO4: Acquiring knowledge on aerofoil nomenclature & characteristics and the Prandtl’s lifting line theory and to do practical problems based on this theory.

CO5: Become Knowledgeable of bluff body aerodynamics: flow separation, unsteady wake characteristics, experimental and numerical methods to investigate bluff body problems.

21TF702 Biofluid mechanics

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Module-1


Heart: Anatomy, Cardiac cycle, circulatory systems, pressure, flow chamber volume and work, Cardiac Muscle, Heart Sounds, Coronary Circulation, Cardiac Conduction, ECG and Wiggers diagram.


Module-2


Module-3


Native Heart Valves: Aortic and Pulmonary Valves, Mitral and Tricuspid Valves.


TEXT BOOKS/REFERENCES


Course Outcomes

CO1: Fluid and solid mechanics that are pertinent to blood flow in the heart and blood vessels.
CO2: Physiology and function of heat.
CO3: Hematology, Blood Rheology and models for Viscosity of Blood,
CO4: Structure of Arteries and Veins.
CO5: Macrocirculation System
CO6: Steady Blood Flow and application of flow models
CO7: Unsteady blood flow in rigid and collapsible tubes
CO8: Microcirculation System, interstitial fluid flow, mass and heat transport
CO9: Biofluid Dynamics in Human Organs,
CO10: Analysis of blood flow in Native Heart Valves and Implantable Devices
CO11: Computational Fluid Dynamic Analysis of the Human Circulation
CO12: Fluid Structure Interaction Modelling

21TF703 Boundary Layer Theory
L T P C
3 0 0 3

Module-1

Introduction: Ideal and real fluids, Boundary-Layer concept, Laminar boundary layer, turbulent boundary layer, Separation of boundary layer, Navier- Stokes equations, Laminar Boundary Layer Equation: Two dimensional equations, displacement and momentum thickness, general properties of the boundary layer equations, wall friction, drag and lift.
Module-2


Module-3

Turbulent Boundary Layer: Mean motion and fluctuations, Equations for turbulent flows, Prandtl’s mixing layer Karman’s hypothesis. Thermal Boundary Layers: Effect of Prandtl Number, Similar solution of thermal boundary layer, Integral method for computing heat transfer, Coupling of the velocity field to the temperature field. Boundary layer in non-Newtonian flows, Boundary layer in Magnetohydrodynamics.

Separation in adverse pressure gradients. Concept of and occurrence in steady flows, and at rear stagnation point of impulsively started cylinder. Form of skin friction near separation point: Goldstein singularity.

Introduction to interactive boundary layers. Goldstein near wake. Trailing-edge triple deck.

TEXTBOOKS/REFERENCES


Course Outcomes

CO1: Understand the concept of hydrodynamic boundary layer and derive the boundary layer equations.

CO2: Identify the effective method for boundary layer control and apply the appropriate method for optimized design.

CO3: Understand the concept of thermal boundary layer and its control.
Module-1


Flow over non-circular cylinders – Influence of geometry and Re- flow separation- wake structures – vortex shedding and induced forces. FSI in biological systems: blood flow through arteries and veins-diagnosis of diseases.

Module-2


Flow interference between non-circular cylinders - influence of Re - body geometry – spacing – differences and similarities with circular cylinders.

Module-3


Some practical problems: Tube bundle vibrations in heat exchangers and nuclear reactors- Vibrations of stacks and other tall structures, transmission line vibrations. Passive and active control of FIV. Energy extraction from FIV. FIV in Engineering Codes. Experimental measurements, flow visualization techniques

TEXT BOOKS/REFERENCES

Course Outcomes

CO1: Develop fundamental knowledge in FSI
CO2: Development of capability to analyse fluid flows of different types associated with different engineering situations involving FSI
CO3: Develop skill to propose solutions to FSI problems and cater to industrial needs
CO4: Academic capability to conduct research activities in the area of FSI.

**21TF705 Introduction to Turbulence**

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Module-1


Module-2

Numerical Turbulence modelling: Reynolds averaging technique, Reynolds stress, RANS model, one-, two- and multiple equations for turbulence modelling, Spalart-Allmaras model, k-epsilon models, k-omega models, SST k-omega models and RSM. Introduction to Large eddy simulation (LES) and Direct Numerical Simulation (DNS) method. Implementation and verification of the different turbulent models in real-life turbulent flow problems using CFD software.

Module-3


**TEXT BOOKS/REFERENCES**

Course Outcomes

CO1: To understand the concept and origin of turbulence and the fundamental characteristics of turbulent flows

CO2: The study the concept of closure problem, energy spectra, eddy viscosity, Reynolds stress etc.

CO3: To understand the concept of statistical turbulence, Kolmogorov’s hypothesis, space-time correlation methods, spectral methods etc.

CO4: To understand concept time, space and ensemble averaging, Numerical Turbulence modelling, one-, two- and multiple equations for turbulence modelling, RSM, LES and DNS methods

CO5: To study experimental measurement of turbulence such as hot wire anemometer, laser Doppler anemometer etc.

Thermal Stream Electives

21TF711 Computational methods for Micro and Nano Scale Thermal Systems

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Module-1

Introduction: Computational simulation, need for discrete computation.


Module-2

Statistical Mechanics: Review of probability and statistics, quantum states of a system, equations of state, canonical and microcanonical ensemble, partition function, energy levels for molecules, equipartition theorem, minimizing the free energy, partition function for identical particles, Maxwell distribution of molecular speeds.

Module-3

Atomistic Simulation Techniques: Molecular Dynamics (MD), Monte Carlo (MC), Direct Simulation Monte Carlo (DSMC) Methods.

TEXT BOOKS/REFERENCES

Course Outcomes
CO1: To gain knowledge on fundamental topics like classical mechanics and statistical mechanics.
CO2: Have exposure about atomistic simulation techniques and its applications.
CO3: Have exposure about multiscale simulation methods.
CO4: To identify, formulate, and solve interdisciplinary problems relevant for nanoscale systems.

21TF712 Cryogenics

Module-1
Introduction to Cryogenic Systems: Historical development, Applications of Cryogenics (Space, Food Processing, Superconductivity, Electrical Power, Biology, Medicine, Electronics and Cutting Tool Industry).


Module-2
Module-3


Cryogenic engine injectors (subcritical & super critical)


TEXT BOOKS/REFERENCES


Course Outcomes

CO1: Understand properties of material at cryogenic temperatures.
CO2: Know about various liquefaction systems
CO3: Get ideas on cryogenic refrigeration systems, cryogenic instrumentation and cryogenic heat exchangers

21TF713

Heat Exchange Equipment

L  T  P  C
3  0  0  3

Module-1

Introduction: Classification of heat exchangers, design of heat exchangers: engineering design- steps for designing, design a workable system, optimum systems, economics, probabilistic approach to design, sizing and rating problems; LMTD and $\varepsilon$-NTU approach of design. Introduction to design codes (ASME, TEMA, HTRI etc)

Design of double pipe heat exchangers: introduction, basic design procedure and theory, overall heat transfer coefficient, fouling factors, fins, weighted fin efficiency, pressure drop analysis, design problems. Introduction to three fluid/ multi fluid heat exchanger behaviour.

Design of shell and tube heat exchangers – basic design procedure and theory, shell and tube exchangers: construction details, general design considerations: fluid allocation, shell and tube fluid velocities, tube-side and shell side heat-transfer coefficient and pressure drop, Kern’s method, design problems.
Module-2

Design of Condenser: Heat-transfer fundamentals, Condensation of steam, Condensation inside and outside horizontal tubes, Condensation inside and outside vertical tubes, De-superheating and sub-cooling, Pressure drop in condensers, design problems.

Design of Compact heat exchanger: introduction, design procedure of compact heat exchanger, pressure drop analysis of plate fin heat exchanger, problems. Plate heat exchanger: Gasketed plate heat exchangers, Welded plate, advantages and disadvantages over the other heat exchangers, design procedure, heat transfer coefficient and pressure drop calculation on both the sides of exchanger, problems on plate exchanger.

Module-3

Thermal design of heat exchanger such as Regenerative heat exchanger, Super heater, Air pre-heaters, analysis and design of cooling towers.

Heat pipe: introduction, working principle, working fluids, wick structure and material, classification of heat pipe, pressure variation along the heat pipe, limitations of a heat pipe, problems on heat pipe.

TEXTBOOKS/REFERENCES


Course Outcomes

CO1: Background, Application, Classification and Common terminologies of Heat exchangers
CO2: Design of Tubular Heat Exchangers
CO3: Design of Regenerative and Compact Heat exchangers
CO4: Design concepts of Heat Pipes.

21TF714 HVAC and Refrigeration

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Module-1


Module-2

Module-3


TEXTBOOKS/REFERENCES


Course Outcomes

CO1: Identify the suitability of refrigeration systems
CO2: Select refrigerants and components like evaporator, compressor, condenser, expansion devices etc. based on operational characteristics
CO3: Design of refrigeration and air-conditioning systems using fundamentals of heat and mass transfer principles
CO4: Evaluate the performance of an air-conditioning system
CO5: Estimate cooling / heating load for given application

21TF715 IC Engine Systems, Combustion and Emissions

L   T   P   C
3   0   0   3

Module-1

Constructional features of different types of internal combustion engines, SI Engine introduction, carburetion mixture requirements, Fuel supply. Thermo-chemistry and thermodynamics of combustion, Laminar and turbulent premixed flames, Premixed engine combustion, Ignition, Stages of combustion, Normal and abnormal combustion, factors affecting knock, Combustion chambers.

Module-2

CI engine, Injection Systems, Spray formation and atomization, Combustion systems and management, Mechanical and electronic-Combustion in CI engines-stages of combustion-Factors affecting combustion, Direct and indirect injection systems. Introduction to Turbo charging and supercharging.
Basic concepts of engine simulation, governing equations, simulation of various engine processes for SI and CI Engines. Alternate fuels for SI and CI engines.

Module-3

Chemical equilibrium analysis (BOL and EOL), Application of NACA – CEA code.

Introduction to air pollutants and pollution; Genesis and formation of engine emissions, NO kinetics, Soot formation and oxidation, NOx-Soot trade off. Control of emissions in SI and CI engines, Impact of engine design parameters on emissions, exhaust after treatment, lean de-NOx catalysts.

TEXT BOOKS/REFERENCES


Course Outcomes

CO1: Understand the constructional features and systems of different types of internal combustion engines.

CO2: Understand basic concepts of engine simulation and performance optimization.

CO3: To familiarize the mechanism of combustion, pollutant formation and its control.

21TF716 Inverse Heat Transfer  L  T  P  C
3  0  0  3

Module-1


Module-2

Linear and non-linear optimisation problems, Parameter estimation, Gradient descend methods, Levenberg-Marquard method, Conjugate gradient method, Adjoint problem. Review of governing equations of heat transfer and fluid flow problems, inverse problems, examples, Methods of design of experiments

Differential Evolution Techniques’ (genetic algorithm based).
Module-3


TEXT BOOKS/REFERENCES


Course Outcomes

CO1: Capability to understand mathematical background of inverse problems.
CO2: Capability to understand the nature of mathematical models and methods to solve them.
CO3: Capability to convert parameter estimation problems into optimization problems and solve them.
CO4: Capability to formulate inverse problems in heat transfer and select appropriate method to solve.
CO5: Capability of identify research problems in design of systems involving heat transfer.

21TF717 Micro and Nano Scale Thermal Engineering  

Module 1

Physics of miniaturisation – scaling laws.
Microscale Energy Transport in Solids: Microstructure of solids, crystal vibrations and phonons, photon interactions, particle transport theories, non-equilibrium energy transfer.
Molecular Forces and Phase Change in Thin Liquid Films: Thermodynamics of thin films, interfacial meniscus properties, interfacial mass flux.
Heat Transfer and Pressure Drops in Microchannels: Single phase and two phase flow, flow boiling, dryout, bubble behaviour, flow pattern.

Module 2

Microfluidics: Introduction, continuum assumption, pressure driven micro flows, boundary condition in fluid mechanics, surface tension driven flows, Electrokinetic Flows.
Nanofluidics: Simple Fluids in Nanochannels, Water in nanochannels, nanofluidic energy conversion.
Module 3

Micro Heat Pipes: Fundamental operating principles, steady state and transient modeling and construction techniques.


Drug delivery, lab on chip devices, BioMEMS.

TEXT BOOKS/REFERENCES


Course Outcomes

CO1: To familiarise with the scaling of forces with system size and the associated changes in the physical behavior of micro/nano scale systems.

CO2: To gain a fundamental understanding about the thermal transport in micro/nano scale systems.

CO3: To familiarise with methods used for analysing fluid transport in micro/nano scale systems.

CO4: To identify, formulate, and solve interdisciplinary problems relevant for micro and nano scale thermal and fluid systems.

21TF718 Two-phase Flow and Heat Transfer

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Module-1

Introduction to phase change flow and heat transfer technology, Various industrial applications, Review of one-dimensional conservation equations in single phase flows, Types of flow, volumetric concentration, void fraction, volumetric flux, relative velocity, drift velocity, flow regimes, flow pattern maps, analytical models.

Interfacial tension, wetting phenomenon and contact angles, Phase stability and nucleation.
Homogeneous Flow: One dimensional steady homogeneous equilibrium flow, homogeneous friction factor, turbulent flow friction factor.

Module-2


Drift Flow Model: General theory, gravity flows with no wall shear, correction to simple theory, Armond or Bankoff flow parameters.


Module-3

Condensation: Nusselt theory, Film and drop-wise condensation, boundary layer treatment of laminar film condensation, condensation in vertical and horizontal tubes, condensation inside a horizontal tube.


Molecular Dynamics: Boiling, Condensation, Solid-Liquid Flow, Gas-Solid-Flow.

TEXT BOOKS/REFERENCES


Course Outcomes

CO1: Describe the most important phenomena and principles of two-phase flow in engineering applications
CO2: Apply the basic two-phase models and flow pattern maps to calculate the pressure drops of two-phase flow at various conditions.
CO3: Explain the main points of boiling and condensation, heat transfer, and their enhancement methods
CO4: Describe the concept boiling crisis (e.g., DNB - departure from nucleate boiling, and dryout) and its modelling
CO5: Apply the models of critical flow and flooding to analyze limiting flow of engineering processes.

CO6: Understand the current status to write a scientific review for a topic in the field of two-phase flow and heat transfer and identify problem for research

**Automation / Energy Systems Electives**

**21TF721 Fuel Cell Technology and Hydrogen Energy**

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Module-1

Module-2

Module-3
Hydrogen as a source of energy, physical and chemical properties, suitability of hydrogen as a fuel, salient characteristics, relevant issues and concerns.

Production of hydrogen, thermal-Steam reformation, gasification and woody biomass conversion, partial oxidation methods, biological hydrogen production, photo dissociation, direct thermal or catalytic splitting of water.

General storage methods, compressed storage-composite cylinders, metal hydride storage, carbon based materials for hydrogen storage. Safety aspects of hydrogen storage and handling.

**TEXTBOOKS/REFERENCES**


Course Outcomes

CO1: Understand and apply the basic thermodynamic and electrochemistry to fuel cell systems.

CO2: Understand the effect of operating conditions on the performance of the fuel cell.

CO3: Students able to understand and demonstrate the hydrogen production technologies, storage methods and strategies for transition to hydrogen economy

Module-1

**Instrumentation:** Introduction: Measurement and its classification by physical characteristics, direct and inferential measurement, on- and off-line measurement.


Sensor and Transducers: Classification, principles and applications, interpretation of performance specification of transducers.

Building Blocks of an Instrument: Transducer, amplifier, signal conditioner, signal isolation, signal transmitter, display, data acquisition modules, I/O devices, interfaces. Process

Instrumentation: Working principles of transducers/instruments employed for the measurement of flow, level, pressure, temperature, density, viscosity, etc. and their merits and demerits.

Module-2

Data Acquisition and Signal Processing: Systems for data acquisition and processing, modules and computerized data system, digitization rate, time and frequency domain representation of signals, and Nyquist criterion; Introduction to LabView and Matlab for data capture and analysis.

**Process Control:** Introduction: The concept of process dynamics and control, review of Laplace transform methods, Laplace transform of disturbances and building functions, dynamic model building of simple systems.

Linear Open Loop System: Physical examples of first order systems and their response for step, impulse and sinusoidal inputs, linearization of nonlinear models, response of first order system in series, examples of second order systems and their response.

Linear Closed Loop System: The control system and its elements, closed loop transfer functions, transient response of simple control systems, concept of stability and use of Routh-Hurwitz test for stability.
Module-3

Controllers: Modes of control action, control system and its closed-loop transfer function.

Root Locus Method: Root locus treatment, response from root locus and its application to control system design.

Frequency Response: Introduction to frequency response, Bode diagrams of simple systems, Bode stability criterion, Control system design by frequency response, use of gain and phase margins.


Process Automation, Role of digital computer system in process control, Distributed instrumentation and control system, PLC, DCS, SCADA.

TEXTBOOKS/REFERENCES


Course Outcomes

CO1: Understand basic principles and importance of process control in industrial process plants.
CO2: Estimate various characteristics of instruments
CO3: Study working of sensors and transducers and understand building blocks of instruments
CO4: Familiarisation with Data Acquisition and Signal Processing
CO5: Analyse and design Linear Open and Closed Loop Systems
CO6: Controllers and Modes of control action
CO7: Frequency Response analysis
CO8: Plant-wide monitoring & control
CO9: Process Automation and Distributed instrumentation and control system.
Module-1


Module-2


Module-3

Applications of POD and DMD for Thermal and Fluid systems: Introduction to coherent structures, Turbulence, Jet flows, boundary layer, flows in complex geometries, flows in internal combustion engines.

TEXTBOOKS/REFERENCES


Course outcomes

CO1: To gain fundamental knowledge on the basic concepts and theoretical ideas in data-driven techniques in the context of programming language infrastructure.
CO2: To develop an understanding of the algorithms used for transforming and reducing data.
CO3: To implement the various theoretical and computational tools on scientific applications relevant for thermal and fluid systems.
Module-1

Mathematical concept review: Linear algebra and Probability, Introduction to Machine learning, Terminologies in machine learning, Types of machine learning, Linear Regression, Multivariate Regression, Bias Variance, Classification of Linear models, Bayesian Classifiers.

Module-2

Regularization, Hyper-parameter Tuning, Subset selection, shrinkage method, Dimensionality Reduction, Evaluation measures, Decision trees, Ensemble models – Bagging and Boosting, Random Forest.

Module-3


TEXT BOOKS/REFERENCES


CO1: Develop a good understanding of fundamental principles of machine learning.
CO3: Develop a model using supervised/unsupervised machine learning algorithms for classification/prediction/clustering.
CO4: Evaluate performance of various machine learning algorithms on various data sets of a domain.
CO5: Design and Concrete implementations of various machine learning algorithms to solve a given problem using languages such as Python.
Module 1

Module 2
Heat generation in fuel, coolant, structural and shield materials and decay heat, Nuclear Heat Transport, steady and unsteady conduction in fuel, cladding, and structural materials elements, Multi-dimensional thermal-hydraulics in plenum.
Hydraulics of reactor system loops, Hydraulics of heated channels.
Thermal stratification, thermal shock, thermal fatigue, gas entrainment, steam-liquid droplet separation.
Safety philosophy, Thermal Design Principles, Single Channel Analysis, Sub-channel analysis, LOCA and LOFA Modelling, modelling of containment loading. Waste management. Indian nuclear power program.

Module 3
Nuclear Instrumentation, Health Physics, Radiation Shielding.
Thermal-Hydraulics Uncertainty Analysis, Probabilistic safety assessment, regulatory procedure and licensing.

TEXT BOOKS/REFERENCES
Course Outcomes

CO1: Application of reactor physics concepts and working of thermal and fast reactors
CO2: Understanding of two-phase flows, boiling, condensation, Critical Heat Flux
CO3: Heat generation and transport in reactor
CO4: Thermal hydraulic phenomena inside reactor vessel and components
CO5: Safety principles and safety evaluation
CO6: Nuclear instrumentation and health physics
CO7: Analysis of Transient and Accidents.
CO8: Licencing aspects

21TF726 Power Plant and Thermal Systems Engineering

Module-1

Module-2
Coal based plants: Analysis of steam cycles, Feedwater heaters, Deaerator and drain cooler, Optimization of cycle parameters, reheat and regeneration, Analysis of multi-fluid coupled cycles, Cogeneration of power and process heat. Thermal power plant equipment, Combustion mechanisms, Furnaces, Combustion control, boilers (coal based, RDF based), economizers, Feedwater treatment, feed water heater, Boiler maintenance, ash handling system, Dust collection system Operation and maintenance of steam power plant, heat balance and efficiency, Site selection of a steam power plant
Gas turbine plants: Layout of gas turbine power plant, Elements of gas turbine power plants, Gas turbine fuels, cogeneration, auxiliary systems such as fuel, controls and lubrication, operation and maintenance, Combined cycle power plants, Site selection of gas turbine power plant.

Module-3
Diesel based plants: General layout, Components of Diesel power plant, Performance of diesel power plant, fuel system, lubrication system, air intake and admission system, supercharging system, exhaust system, diesel plant operation and efficiency, heat balance, Site selection of diesel power plant, Comparative study of diesel power plant with steam power plant.
Nuclear based plants: Elements of nuclear power plants, nuclear reactors and fuels. New generation power plants.
Renewable energy: solar, geothermal, wind, biomass, ocean, fuel cells, Environmental aspects of power generation, sustainability and future scenarios.

Negative emission power plants: Introduction, thermodynamics, carbon capture and utilization, techno-economic aspects.

TEXT BOOKS/REFERENCES


Course Outcomes

CO1: Skill to identify suitable thermal plant for power generation based on techno-economic considerations.

CO2: Ability to do site selection for a power plant.

CO3: Ability to analyse the performance of thermal power plants.

CO4: Skill to suggest methods for improving the performance of power plants.

CO5: Skill to undertake research studies in conventional and non-conventional power plants

21TF727 Renewable Energy L T P C

Module-1

Renewable energy sources in India-potential sites, availability.

Solar Energy: measurement and collection, flat plate collectors, concentrating collectors, solar ponds, photovoltaic conversion, Thermal energy storage, Potential and scope of solar cooling, Types of solar cooling systems.

Ocean Energy: Principles of OTEC (Ocean Thermal Energy Conversion) - wave energy, tidal energy, energy conversion systems.

Module-2


Bio-fuels: Sources and potential, properties and characterization; Biogas generation through aerobic and anaerobic digestion, bio-diesel and ethanol production and utilization. Thermo-chemical methods of biofuel utilization: Combustion and gasification; utilization of producer gas for thermal and electricity generation.
Module-3

Geo-thermal Energy - nature, types and utilization.
Recent trends in renewable energy- Flow Induced Vibration as a source of energy, Hydrogen energy.
Applications: Applications of renewable energy sources-typical examples. Energy audit.

TEXT BOOKS/REFERENCES


Course outcome

CO1: Explain the technical functioning and principles of various techniques for the utilisation and conversion of renewable energy

CO2: Mathematically illustrate and model renewable energy processes and perform calculations for different technical solutions

CO3: Identify different challenges in implementation of different renewable energy systems.

CO4: Identify the scope of further research in each renewable energy technology.

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Module-1


Module-2

and turbine cascade performance - correlations for turbine and compressor performance, Hawthorne’s
correlation - Soderberg’s correlation

Module-3

Axial flow machines: turbines, compressors, and fans - two-dimensional theory - Velocity diagram
- stage losses and efficiency - design and off-design characteristics, Centrifugal compressors –
theoretical analysis – impeller, diffuser and casing - optimum design of compressor - inlet pre-whirl
- slip factor - pressure ratio - choking in a compressor stage - surge, and stall. Radial flow turbines:
types of inlet flow – efficiency - off-design characteristics - loss coefficients.

Experiments and CFD: Experimental methods to measure flow and thermal fields in turbomachines
– Application of CFD in analysis and design of turbomachinery.

TEXT BOOKS/REFERENCES

2011.
[4] P N Modi., S.M. Seth., Hydraulics and Fluid Mechanics including Hydraulic Machines,

Course Outcomes

CO1: Capability to analyse the performance of turbo machines
CO2: Ability to select turbo machines for different applications
CO3: Predict performance of turbo machine using model analysis
CO4: Conduct research studies on turbomachines to improve their performance