Scheme for B.Tech. Mechanical Engineering with Honors in Advanced Thermal Systems

Department of Mechanical Engineering

		Advanced Thermal Systems					
1		Advanced Fluid Mechanics	V	3	0	0	3
2		Numerical Methods and Data Visualization	V	2	1	0	3
3		A. Design of Heat Exchanger / B. Environment, Social and Governance	VI	2	1	0	3
4		High Performance computing and AI in thermal-fluid system	VI	2	1	0	3
5		A. Computational Heat Transfer / B. Experimental Methods in Thermal Sciences	VII	3	0	0	3
6		Thermal simulation Lab & Mini Project	VIII	0	0	6	3

DUGC Convenor

Head, ME

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	Advanced Fluid Mechanics	**3**	**3**	**0**	**0**	**0**

PREREQUISTE:
Engineering Thermodynamics, Basic Fluid Mechanics, Calculus, Differential Equations

COURSE OUTCOMES:

CO1	Apply the principles of fluid mechanics, including fluid properties, fluid statics, and fluid dynamics, to analyze and solve complex problems related to fluid flow using lower-order thinking skills
CO2	Analyze and evaluate the governing equations of fluid dynamics, including the Navier-Stokes equations, to predict and interpret fluid behavior in various flow regimes using higher-order thinking skills
CO3	Design and optimize complex fluid systems for specific applications using higher-order thinking skills
CO4	Propose and evaluate innovative solutions to engineering problems related to fluid dynamics in various fields, such as aerodynamics, hydrodynamics, and biomedical engineering, using higher-order thinking skills

COURSE CONTENTS:

Introduction and Fundamental Concepts: Review of basic fluid mechanics concepts, Conservation laws: mass, momentum, and energy; Continuum hypothesis; Steady and unsteady flows; Stream functions and velocity potentials; and Navier-Stokes equations.

Cartesian Tensor: Scalars; Vectors; Tensors; Notations; Second Order tensor; Force on a surface; Kronecker Delta and Alternating Tensor; Vector, Dot and Cross Products; Gradient, Divergence and Curl; Symmetric and Anti-symmetric Tensors; Gauss and Stokes Theorem

Basic Equations: Deformation and the rate of strain; the deformation tensor; skew-symmetry of the deformation tensor; symmetry of the stress tensor; Stockessian and Newtonian fluids; Reynolds transport theorem and integral forms of conservation laws; Derivation of the general differential equation of continuity; Momentum and Energy in tensorial form; Euler's and Navier-Stoke's equations; Integration of the momentum equation and the generalized Bernoulli's equation.

Two Dimensional Irrotational Flow: Two-dimensional flow in rectangular and polar coordinates; Continuity equation and the stream function; Irrotationality and the velocity potential function; Vorticity and circulation; Plane potential flow and the complex potential function; Sources, sinks, doublets and vortices; Superposition of uniform stream with above; flow around corners; Rankine ovals, Flow around circular cylinders with the without circulation; Pressure distribution on the surface of these bodies.

Viscous Flow: Exact solution; Plane Poiseuille and Couette flows; Hagen Poiseuille flow through pipe and 2D channel; Flows with very small Reynolds number; Flows with very large Reynolds number; Elements of two dimensional boundary layer theory; Displacement thickness and momentum thickness; Skin friction; Flow around immersed bodies: drag, lift, and boundary layer control, introduction to turbulent flow.

TEXT BOOKS/ REFERENCE BOOKS

1. Advanced Engineering Fluid Mechanics. K. Muralidhar, G. Biswas, Alpha Science International Ltd. 2005.
2. Fluid Mechanics, Pijush K Kundu, Ira M Cohen, Academic Press, 2015
3. Viscous fluid flow , F. M. White, I Corfield, McGraw-Hill, 2006.
4. Introduction to Fluid Dynamics, "G.K. Batchelor" Cambridge press, 2000.
5. Introduction to Fluid Dynmaics, Robert W Fox, Alan T MacDonald, Philip J Pitchard, John Wiley & Sons Inc. 2010

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DETAILS OF THE COURSE: Honours Advanced Thermal Systems

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
	Numerical Methods and Data Visualization	3	2	1	0	0

PREREQUISITE : Basic knowledge of calculus, linear algebra, and programming concepts

COURSE OUTCOMES:

CO1	Understand the basics of numerical methods and data visualization
CO2	Gain hands-on experience in solving mathematical problems using numerical methods
CO3	to analyze basic numerical techniques and write scientific computation programs
CO4	Develop skills in creating visualizations of numerical data

COURSE CONTENTS

Introduction to Numerical Methods and Data Visualization: Overview of numerical methods and data visualization, Applications of numerical methods and data;

Interpolation: Linear interpolation, Polynomial interpolation, Splines;

Numerical Integration : Trapezoidal rule, Simpson's rule, Monte Carlo integration;

Differential Equations : Euler's method, Runge-Kutta method, Boundary value problems;

Data Visualization : Plotting of state variables and derived variables from raw data, Line plots, Scatter plots, Bar plots, Histograms, Heatmaps, Surface plots, streamlines, vector plots.

TEXT BOOKS/ REFERENCE BOOKS:-

1. Numerical Methods for Engineers, Steven C. Chapra and Raymond P. Canale, McGrawHill, 2018.

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Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
	Design of Heat Exchangers	3	3	0	0	0

PREREQUISITE : Fluid Mechanics, Heat Transfer.

COURSE OUTCOMES:

CO1	To develop understanding about the working principle of different heat exchanger(s)
CO2	To be able to select/ propose potential heat exchanger(s) for the given application
CO3	To develop understanding about the factors affecting effectiveness of heat exchanger(s)
CO4	To be able to solve engineering problems involving rating and sizing of heat exchanger(s)
CO5	To be able to analyze the factors causing performance decline and corrective measures

COURSE CONTENTS

Basic Design Methodologies: Classification of heat exchanger, selection of heat exchanger, thermo-hydraulic fundamentals, Overall heat transfer coefficient, LMTD method for heat exchanger analysis for parallel, counter, multi-pass and cross flow heat exchanger, e-NTU method for heat exchanger analysis, Rating and sizing problems, heat exchanger design methodology. Fouling of heat exchangers and effect of fouling, design of heat exchangers subject to fouling, fouling resistance, cleanliness factor, fouling prevention techniques.

Double Pipe Heat Exchangers: Thermal design of inner tube and annulus, hairpin heat exchanger with bare and finned inner tube, parallel and series arrangements, pressure drop. Shell & Tube Heat Exchangers: Basic components, preliminary design procedure, TEMA code.

Compact Heat Exchangers: Heat transfer enhancement, fundamental of extended surfaces (fins). Finned tube heat exchanger, types. Plate fin heat exchanger (PFHE), construction, types, design, application, performance characteristics.

Phase change Heat Exchangers: Evaporators and condensers, types, design and operational considerations. Heat pipes, construction, working principle, application, effect of working fluid and operating temperatures, types of heat pipes.

Direct contact Heat Exchangers: Cooling towers, types, application, basic relations, thermal characteristics, effect of packing, maintenance, environmental effects, wind load, typical installations.

TEXT BOOKS/ REFERENCE BOOKS-

1. Fundamentals of Heat Exchanger Design by Ramesh K Shah, Wiley Publication, 2003.
2. Heat Exchanger Selection, Rating and Thermal Design by Sadik, Kakac, CRC Press.
3. Compact Heat Exchangers by Kays, V.A. and London, A.L., McGraw Hill.
4. Heat Exchanger Design Handbook by Kuppan, T, Macel Dekker, CRC Press.

ONLINE/E RESOURCES

NPTEL, Heat Exchangers: Fundamentals and Design Analysis, IIT Kharagpur, Prof. Prasanta Kr Das, Prof. Indranil Ghosh (https://nptel.ac.in/courses/112105248)

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Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
	Environmental, Social, and Governance	**3**	**2**	**1**	**0**	**0**

PREREQUISITE : None

COURSE OUTCOMES:

CO1	Understand the basics of ESG and its importance in contemporary society
CO2	Learn to analyze and evaluate the ESG performance of companies and investment opportunities Develop skills in communicating and reporting ESG information effectively
CO3	Develop skills in analyzing and interpreting heat transfer simulations Develop skills in communicating and reporting ESG information effectively
CO4	Apply ESG concepts to real-world problems

COURSE CONTENTS

Introduction to ESG: Overview of ESG and its relevance in contemporary society, History and evolution of ESG.
Environmental Issues: Climate change and carbon emissions, Biodiversity and ecosystem degradation, Waste management and resource depletion.
Social Issues: Labor and human rights, Community engagement and development, Diversity and inclusion.
Governance Issues: Corporate governance and ethics, Executive compensation and incentives, Shareholder rights and activism
ESG Investment and Reporting: ESG investment strategies and performance metrics, ESG disclosure and reporting frameworks, ESG analysis and ratings.
Case Studies and Real-World Applications: Examples of ESG in action, including company case studies, Current events and issues related to ESG

TEXT BOOKS/ REFERENCE BOOKS:-

1. "ESG Investing: Theory, Evidence, and Practice" by Amir Amel-Zadeh and George Serafeim
2. "The ESG Handbook: A Practitioner's Guide to Environmental, Social, and Governance Issues in Investing" by Michael J. Oliver Weinberg and Lara Hussain
3. "The Handbook of Environmental, Social, and Governance (ESG) Investing" edited by Samuel A. DiPiazza Jr. and George Serafeim

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DETAILS OF THE COURSE: Honours Advanced Thermal Systems

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
	High Performance computing and AI in thermal-fluid system	**3**	**2**	**1**	**0**	**0**

PREREQUISITE : Numerical Techniques, Basic Thermal-fluid mechanics, Calculus and differential Equations, Linear Algebra, FORTRAN/ /Python

COURSE OUTCOMES:

CO1	Understand the fundamental concepts of high-performance computing and artificial intelligence in thermal-fluid systems
CO2	Apply computational tools and algorithms to optimize thermal-fluid system performance using high-performance computing and AI techniques.
CO3	Evaluate the effectiveness and efficiency of high-performance computing and AI methods in solving complex thermal-fluid system problems.
CO4	Design and implement advanced algorithms integrating high-performance computing and AI to solve real-world thermal-fluid system challenges.

COURSE CONTENTS

Introduction to High Performance Computing (HPC)
Introduction to parallel computing; Key concepts: parallelism, concurrency, scalability, performance; Parallel computing architectures; Shared and distributed memory

Paralleization and MPI
Parallelization of numerical algorithms; Parallel programming paradigms: message passing, threads, OpenMP, MPI, CUDA; Message passing interface (MPI)

Application of high-performance techniques in Thermal-Fluid Systems
Domain decomposition techniques; Load balancing; Parallel I/O

Artificial Intelligence for Thermal Systems
Introduction to artificial intelligence and machine learning; Supervised and unsupervised learning algorithms; Regression and classification; Neural networks for predicting temperature and flow distributions; Convolutional neural networks for analyzing thermal images; Reinforcement learning for optimizing thermal systems

TEXT BOOKS/ REFERENCE BOOKS:-

1. Introduction to High Performance Computing for Scientists and Engineers, Georg Hager, Gerhard Wellein
2. Using HPC for Computational Fluid Dynamics: A Guide to High Performance Computing for CFD Engineers,Shamoon Jamshed
3. High-Performance Computing for Fluid Dynamics: Theory, Algorithms, and Applications" by H. Fujii and K. Nakahashi
4. Artificial Intelligence in Engineering Design and Learning, edited by C. Tong, et al.
5. Convolutional Neural Networks in Visual Computing: A Concise Guide, G. Liu, et al.
6. Reinforcement Learning: An Introduction, R. S. Sutton and A. G. Barto

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DETAILS OF THE COURSE: Honours Advanced Thermal Systems

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
	Computational Heat Transfer	3	3	0	0	0

PREREQUISITE : Heat transfer, Thermodynamics

COURSE OUTCOMES:

CO1	Learn to model and simulate heat transfer using numerical methods and software tools
CO2	Understand the concepts of stability, convergence, consistency and accuracy of numerical schemes and better assess the results produced
CO3	Develop skills in analyzing and interpreting heat transfer simulations
CO4	Apply computational heat transfer techniques to solve practical problems

COURSE CONTENTS

Introduction to heat transfer and numerical methods: Overview of heat transfer mechanisms and applications; Methods of prediction, potential and limitation of CFD/CHT; Review of numerical techniques: Solution of IVP and BVP, Euler method, Runge-Kutta method, accuracy and errors, solution of linear algebraic equations, convergence.

Modelling of conduction heat transfer: Analytical and numerical methods for solving conduction problems, Boundary and initial conditions for conduction heat transfer, Numerical solution of one dimensional steady state heat conduction, unsteady heat conduction, Crank-Nicolson scheme, ADI scheme, heat conduction in multidimensional cases.

Modelling of convection diffusion problems: One dimensional convection-diffusion using central difference scheme, upwind scheme, transportive property, numerical diffusion (artificial viscosity), higher order schemes.

Modelling of radiation heat transfer: Radiation equations and boundary conditions, Monte Carlo and finite volume methods for radiation heat transfer

TEXT BOOKS/ REFERENCE BOOKS:-

1. An introduction to computational fluid dynamics: the finite volume method, W Malalasekera. Pearson Prentice Hall, 2007.
2. Numerical heat transfer and fluid flow, Suhas Patankar, CRC press, 1980.

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DETAILS OF THE COURSE: Honours Advanced Thermal Systems

Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
	Experimental Methods in Thermal Sciences	3	3	0	0	0

PREREQUISITE : None

COURSE OUTCOMES:

CO1	Understand the basic principles and techniques of experimental methods in thermal sciences
CO2	Learn to design and conduct experiments to measure thermal properties and parameters
CO3	Develop skills in data acquisition, analysis, and interpretation
CO4	Understand the sources and types of experimental uncertainties, and how to quantify them
CO5	Apply experimental methods to solve real-world thermal science problems

COURSE CONTENTS

Introduction to Experimental Methods in Thermal Sciences: Overview of experimental methods in thermal sciences, Types of experiments and experimental design, Measurement and instrumentation

Data Acquisition and Analysis: Signal processing and conditioning, Data acquisition systems, Data reduction and analysis techniques

Uncertainty Analysis: Types and sources of experimental uncertainties, Error analysis and propagation, Statistical analysis of experimental data

Temperature Measurement Techniques: Contact and non-contact temperature measurement techniques, Thermocouples, resistance temperature detectors, and thermistors, Infrared and optical temperature measurement techniques

Flow Measurement Techniques: Flow visualization techniques, Pressure measurement techniques, Velocity measurement techniques.

Heat Transfer Measurement Techniques: Heat flux measurement techniques, Thermal conductivity measurement techniques, Heat transfer coefficient measurement techniques

TEXT BOOKS/ REFERENCE BOOKS:-

1. "Experimental Methods for Engineers" by J.P. Holman
2. "Thermal Measurements and Instrumentation" by Dale P. B

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Course Code	Course Title	Credits	Lecture	Tutorial	Practical	Studio
	Thermal Simulation Lab and Mini Project	3	0	0	6	0

PREREQUISITE : None

COURSE OUTCOMES:

CO1	To learn simulation softwares for thermal systems
CO2	To implement simulation in thermal systems using codes
CO3	To implement knowledge in design of thermal systems
CO4	To convert thermal system designs to build PoC of thermal system based products / processes.

COURSE CONTENTS

- Discretization and numerical solution of 1D steady state heat transfer through a simple fin.
- Numerical solution of transient heat conduction in a square metallic block subjected to Dirichlet, Neumann and mixed boundary conditions at different faces.
- Solution convergence monitoring, flow visualization and post processing techniques and tools
- Introduction to open source CFD software and setup test case-1 for laminar flow in Lid driven cavity
- Grid independence test, results reporting and visualization for test case-1
- Investigating the false diffusion in various discretization schemes.
- CFD study of natural convection in a square cavity (test case-2)
- CFD study of conjugate heat transfer in a heat exchanger (test case-3)
- To obtain performance and emission parameters for single cylinder diesel stationary water-cooled C.I. engine using Diesel R.K. software.
- To obtain volumetric efficiency and plot heat release rate curve for multi cylinder water cooled variable RPM S.I. engine using Diesel R. K. software.