ACADEMIC CURRICULA

POST GRADUATE DEGREE PROGRAMMES

Master of Technology

(Choice Based Flexible Credit System)

Regulations 2021

Volume – 25
Syllabi for School of Mechanical Engineering Programmes

Professional Core and Elective Courses

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

ACADEMIC CURRICULA

School of Mechanical Engineering

Professional Core Course

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21MAC501T	Course Name	COMPUTATIONAL METHODS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	1	0	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mathematics*	Data Book / Codes / Standards	*Statistical Tables*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*learn the concept of one dimensional wave equations and diffusion equation*
CLR-2:	*construct Fourier series for periodic functions and transform technique to solve elliptic equation*
CLR-3:	*understand the concepts of Euler's equations*
CLR-4:	*identify numerical technique to solve algebraic transcendental equations, ODE and PDE*
CLR-5:	*infer the concepts of probability, correlation and regression*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain analytical solution of partial differential equation*	*3*	*3*	
CO-2:	*justify the solution of elliptic type PDE and periodic functions*	*3*	*3*	
CO-3:	*evaluate the solution of functional and vibrational problems*	*3*	*3*	
CO-4:	*adapt numerical solutions for algebraic, transcendental, ODE and PDE*	*3*	*3*	
CO-5:	*solve Statistical problems related to day to day life*	*3*	*3*	

Module-1 - Transform Techniques	***12 Hour***
Laplace transform - Fourier transform - One-dimensional wave equation using Laplace transform methods - Displacements in long string - Longitudinal vibration of an elastic bar - One -dimensional diffusion equation using Fourier transform methods – One-dimensional diffusion equation using Fourier sine transform methods – One-dimensional diffusion equation using Fourier cosine transform methods. .	
Module-2 - Fourier Series and Elliptic Equation	***12 Hour***
Fourier series representation of periodic functions - Fourier transform methods for Laplace equation.	
Module-3 - Calculus of Variations	***12 Hour***
Euler's Equations - Functional involving x, y, y' - Functional on higher order derivatives - Functional dependent on functions of independent variables - Rayleigh-Ritz method.	
Module-4 – Numerical Methods	***12 Hour***
Solution of algebraic and transcendental equations-Iteration method-Newton's method- solution to ODE- Runge Kutta method of 4th order- Milne's predictor corrector method. Solution to PDE- Solution to Laplace equation-Leibman's method- Solution to Poisson equation- Solution to Parabolic type PDE- Bender Schmidt method-Crank Nicholson method.	
Module-5 - Statistical Techniques	***12 Hour***
Random Variables –Discrete and continuous random variables-Mean, median, variance, Standard deviation, moments, skewness, kurtosis, correlation, regression, coherence, multiple and partial correlation.	

Learning Resources	1. *Sankara Rao, K., "Introduction to Partial Differential Equations", PHI, New Delhi, 3rd edition 2011.* 2. *B .V. Ramana, "Higher Engineering Mathematics", McGraw Hill Publication, 2017.* 3. *Elsgolts, L., "Differential Equations and Calculus of Variations", Mir Publishers, Moscow, 2013.*	4. *S. S. Sastry, Introductory Methods of Numerical Analysis, 5thEdition, PH1, 2012* 5. *S.C. Gupta, V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons, 11th Edition, 2015.* 6. *S. Ross, A First Course in Probability, 8th Edition., Pearson Education India, 2010.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	15%	-	15%	-	15%	-
Level 2	*Understand*	25%	-	25%	-	25%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Madhan Shanmugasundaram, Infosys Technologies, madshan@gmail.com*	1. *Prof. Y.V.S.S. Sanyasiraju, IIT Madras, sryedida@iitm.ac.in*	1. *Dr. V. Subburayan, SRMIST*
	2. *Prof. K.C. Sivakumar, IIT Madras, kcskumar@iitm.ac.in*	2. *Dr. P.Sambath. SRM IST*

ACADEMIC CURRICULA

Solar Energy and Thermal Engineering

Professional Elective Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21MEE535T	Course Name	ADVANCED ENERGY STORAGE	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	***Data Book / Codes/Standards***	*Advanced Energy Storage databook*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*familiarize with various forms of energy storage*
CLR-2 :	*be familiar with the modeling of sensible heat storage*
CLR-3 :	*know the concepts and modeling of LHTES systems*
CLR-4 :	*Know the concepts of electrical and electrochemical energy storage*
CLR-5 :	*familiarize with the applications of thermal energy storage*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CLO-1 :	*Identify the need and various forms of energy storage*	3	-	-
CLO-2 :	*Analyze the various models used in sensible heat storage systems*	3	-	-
CLO-3 :	*Analyze the various models used in latent heat storage systems*	3	-	-
CLO-4 :	*Comprehend electrical and electrochemical energy storage principles*	3	-	-
CLO-5 :	*Identify the concepts of thermal storage for various applications*	3	--	

Module-1 - Various forms of Energy Storage	***9 Hour***
Thermal energy storage scenario in India and Global level. Types of energy storage mechanical, chemical, electrical, magnetic, hydrogen, biological medium. Thermal energy storage technologies, need for TES, types of TES, Sensible and latent heat storage material- Classification, Thermo physical properties, selection criteria. Heat transfer fluid – Classification, Thermo physical properties, selection criteria. Case studies on material characterization for thermal storage mediums.	
Module-2 - Modeling of Sensible Heat Storage	***9 Hour***
Single-blow operating model - Infinite fluid heat capacity, negligible temperature gradient in storage material, internal temperature gradient in storage material, Simplified model, Finite conductivity model- slab configuration, Finite conductivity model - hollow cylinder configuration, comparisons of finite conductivity models of hollow cylindrical and slab configurations, Analysis of the effects of finite thermal conductivity, Design of sensible heat thermal energy storage system and case studies on sensible heat storages.	
Module-3 - Modeling of LHTES Systems	***9 Hour***
Modeling of phase change problems, Temperature based model, Enthalpy based model, Porous medium approach, Conduction dominated phase change model, Apparent heat capacity model, Heat transfer with phase change in simple geometries, Packed beds models, Thermal stratification.	
Module-4 – Electrical, Electrochemical and Biogas Energy storage	***9 Hour***

Fundamental concept of batteries, measuring of battery performance, charging and discharging of a battery, storage density, energy density, and safety issues, Types of batteries–Lead Acid, Nickel-Cadmium, Modern batteries, Fuel Cell – types, Case study in electrical energy storage, Principles of Electrochemical storage, Hydrogen - Compressed gas and liquid hydrogen, Metal hydrides, Case study in electrochemical energy storage, Biogas energy storage and applications.	
Module-5 –Thermal Energy Storage Applications	***9 Hour***
Comparison of storage technologies ,Cool storage concept -, Cool thermal storage in process cooling applications, Cool thermal storage in building air conditioning systems, Solar energy storage – Passive heating and cooling, Green house heating, Drying and heating for process industries, Solar power plant applications, Sustainable thermal storage systems-types, Low energy and low carbon thermal storage, Geothermal energy storage and Wind thermal cold energy storage, Hybrid TES and CHP thermal storage, Case studies on hybrid energy storage.	

Learning Resources	*1. Ibrahim Dincer and Marc A. Rosen, "Thermal Energy Storage Systems and Applications", 2nd Edition, John Wiley and Sons Ltd., 2011.* *2. Electrochemical technologies for energy storage and conversion, Ru-shiliu, Leizhang, Xueliangsun,Wiley publications, 2012* *3. Fuel cell systems Explained, James Larminie and Andrew Dicks, Wiley publications, 2003* *4. Luisa F.Cabeza, "Advances in Thermal Energy storage systems, Methods and applications", Wood head Publishing,Elsevier,2015* *5. S.Kalaiselvam and R.Parameshwaran., "Thermal Energy Storage Technologies for sustainability systems Design, assessment and Applications", Elsevier publications ,2014*	*6. Frank W. Schmidt, A. John Willmott, "Thermal Energy Storage and Regeneration", Hemisphere Publishing Co., 1981.* *7. Charles E. Dorgan, James S. Elleson, "Design Guide for Cool Thermal Storage", ASHRAE, Atlanda, 1993.* *8. G. Beckmann, "Thermal Energy Storage: Basics, Design, Applications to power generation and heat supply", Springer, 1984* *9. ASHRAE, "Handbook of Fundamentals", American Society of Heating Refrigeration and Air conditioning Engineers, New York, 2000*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	30%	-	30%	-
Level 2	Understand	30%	-	30%	-	30%	-
Level 3	Apply	20%	-	20%	-	20%	-
Level 4	Analyze	20%	-	20%	-	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Soumitra Mukhopadhyay, SMS India Pvt. Ltd, Kolkatta	*1. Dr. Ravita Lamba, MNIT Jaipur*	*1. Dr.D.Premnath, SRMIST*
2. R. M. Periyasamy, NLC India, Neyveli	*2. Dr. G. Kumaresan, Anna University Chennai*	*2. Dr.R.Senthil, SRMIST*

Course Code	21MEE536J	Course Name	MODELLING AND ANALYSIS OF ENERGY SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on various mathematical techniques*
CLR-2:	*be familiar with various numerical techniques*
CLR-3:	*examine the unconstrained problems*
CLR-4:	*be familiar with various economic models*
CLR-5:	*acquire knowledge on numerical solution of DE*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand and apply the step-in model development*	3	-	-
CO-2:	*identify the different method of solution for nonlinear algebraic equations*	3	-	-
CO-3:	*analyze the unconstrained and constrained problems*	3	-	-
CO-4:	*apply optimization in energy system*	3	-	-
CO-5:	*understand and apply different solution technique for energy system*	3	-	-

Module-1 - Modelling Overview	***9 Hour***
Levels of analysis – steps in model development-examples of models – quantitative techniques – interpolation –polynomial– Lagrangian – curve fitting – regression analysis –solution of transcendental equations. Case studies on regression analysis.	
Module-2 - Systems Simulation	***9 Hour***
Information flow diagram – solution of set of nonlinear algebraic equations – successive substitution – Newton Raphson – examples of energy systems simulation.	
Module-3 - Optimization	***9 Hour***
Objectives/constraints – problem formulation –unconstrained problems – necessary and sufficiency conditions, Constrained optimization, Case studies on optimization techniques.	
Module-4 Dynamic Programming	***9 Hour***
Search Techniques – univariate and multivariate –case studies of optimization in energy systems Dealing with uncertainty- probabilistic techniques – Trade-offs between capital and energy using Pinch analysis, Case studies on dynamic programming.	
Module-5 Energy- Economy Models	***9 Hour***
Scenario generation – input output model, Numerical solution of differential equations – overview – convergence –accuracy – transient analysis – application examples, Case studies on energy-economic models	

Learning Resources	1. *W. F. Stoecker, Design of Thermal Systems, McGraw Hill, 1981.* 2. *Vanek F.M., Albright L.D. Energy Systems Engineering, McGraw-Hill, 2008.*	3. *S. S. Rao, Optimization theory and applications, Wiley Eastern, 1990.* 4. *Vogel. W, Kalb. H, "Large- Scale Solar Thermal Power Technologies", WileyVCH, 2010*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 Practice (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	30%	-	-	-	30%	-
Level 2	*Understand*	30%	-	-	30%	30%	-
Level 3	*Apply*	20%	-	-	30%	20%	-
Level 4	*Analyze*	20%	-	-	20%	20%	-
Level 5	*Evaluate*	-	-	-	20%	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Parag Deshpande, senior scientist, NAL	*1. Dr Aviansh Kumar IITDM Kancheepuram*	*1. Dr. Santosh Kumar Singh, SRMIST*
2. Dr. A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr. Vihnu M Teja IIT ISM Dhanbad*	*2. Dr. M. Gunasekaran, SRMIST*

Course Code	21MEE633J	Course Name	MEASUREMENT TECHNIQUES IN ENERGY SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*learn the basic concepts of measuring systems*
CLR-2:	*understand the concept of dynamic responses*
CLR-3:	*learn different measurement techniques in fluid dynamics*
CLR-4:	*possible applications of measuring techniques*
CLR-5:	*understand the concept of Data Acquisition System (DAQ) and post processing*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the basic concepts of measuring systems*	3	2	-
CO-2:	*discuss the concept of dynamic responses*	3	2	-
CO-3:	*analyze different measurement techniques in fluid dynamics*	3	2	--
CO-4:	*apply the concept of measurement techniques*	3	-	1
CO-5:	*apply the concept of Data Acquisition System (DAQ) and post processing*	3	2	-

Module-1 - Introduction to Measurement Systems	***12 Hour***
General measuring system and their concepts, Static and Dynamic response of measuring systems, Basic methods of measurement, Functional Elements of Measurement Systems, Error analysis–Statistical methods, Measurement errors, Probability distributions, Curve fitting and Signal conditioning, Discretization, and analysis.	
Module-2 - Dynamic Response of Instruments	***12 Hour***
Dynamic performance characteristics, Types of standard input signals, Instrument types –Zero and higher order instruments, First order and second order instrument, Step response and Ramp response of first order system, Impulse response, Frequency response for First and Second order instruments, Response of a general form of instrument to a periodic input, Time and frequency domain specifications, Detailed analysis on measurement system parameters.	
Module-3 - Measurement Techniques	***12 Hour***
Pressure measurement- Manometers, Barometer, Dead weight testers, and Mechanical load gauge, Mechanical pressure transducers- Bourdon tube, Bellows and Capsule, Diaphragm, Electrical pressure transducers – Piezometer, Capacitance, Resistance – Potentiometers, Strain-gauge, LVDT, Piezoelectric transducers and Differential pressure devices, Temperature measurement: Liquid in Glass Thermometer, Gas Thermometer, Velocity Measurement: Hot-wire/Hot-Film & Cold-Wire/Cold-Film Anemometry, Laser Doppler velocimetry, Full-field (2-D) Quantitative imaging techniques like PIV& PLIF	
Module-4 Applications	***12 Hour***
Flow measurements: Obstruction meters – Venturi-meter and Orifice meter, Flow nozzle, Laminarize flow meter and Elbow meter, Pitot tube, Sonic nozzle, Rotameter, Tangent flow meter, and Turbine flow meter, Vortex flow meter, Positive-displacement flow meter, Mass flow meter: Thermal mass flow meter, and Corolis mass flow meter, Hot wire anemometer, Optical Density Based Techniques – Schlieren, Shadowgraph, Strain gauge – Calibration.	

Module-5 Data Acquisition System (DAQ)	12 Hour
Types of Data Acquisition Systems (DAQ), Configuration of DAQ, Signal conditioning, A/D, D/A conversions and Sampling concept, Introduction to digital signal processing Filters, Post processing tools, Case study: Measurement of flow rate using turbulent flow meter, Measurement of pressure using pressure transducer, Measurement of pressure loss in water tunnel, Measurement of temperature using Datalogging system - Agilent	

Learning Resources	1. Tavoularis, Stavros. Measurement in fluid mechanics. Cambridge University Press, 2005. 2. Beckwith, Thomas G., Nelson Lewis Buck, and Roy D. Marangoni. Mechanical measurements. Vol. 5. New York: Addison-Wesley, 1982.	3. Doebelin, Ernest O., and Dhanesh N. Manik. "Measurement systems: application and design." (2007). 4. Holman, Jack Philip. "Experimental methods for engineers." (1966). 5. J. Anthoine, "Measurement Techniques in Fluid Dynamics: An Introduction" Von Karman Institute for Fluid Dynamics, 2009..

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	-	-	20%	-
Level 2	Understand	20%	-	-	20%	20%	-
Level 3	Apply	20%	-	-	20%	20%	-
Level 4	Analyze	20%	-	-	30%	20%	-
Level 5	Evaluate	20%	-	-	30%	20%	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Jayachandran Murugesan, Deputy Manager - Technology & Innovation Thermax Limited, Chennai, India	1. Dr. V. Kumaresan, Anna University, Chennai.	1. Dr. K. Suresh Kumar, SRMIST
2. Mr. Babu P, Head of Innovation at Thermax Limited, India	2. Dr. A. Gurubalan, IIT Bombay, Mumbai	2. Dr. A. Sathishkumar, SRMIST

ACADEMIC CURRICULA

Thermal Engineering

Professional Core Courses

Regulations 2021

SRM
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SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21MEC541J	Course Name	ADVANCED FLUID DYNAMICS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe fundamental equation for a control volume*
CLR-2:	*solve the fluid flow problem using differential analysis*
CLR-3:	*solve the fluid flow problem using integral analysis*
CLR-4:	*identify internal incompressible viscous flow*
CLR-5:	*identify external incompressible viscous flow*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*describe fundamental equation for a control volume*	*3*	-	-
CO-2:	*solve the fluid flow problem using differential approach*	*3*	-	-
CO-3:	*solve the fluid flow problem using integral approach*	*3*	-	-
CO-4:	*identify internal incompressible viscous flow*	*3*	-	-
CO-5:	*identify external incompressible viscous flow*	*3*	-	-

Module-1 - Fundamental Equation	***15 Hour***
Fluid, Newtonian fluid, Eulerian description, Kronecker Delta, Rotational flow, *Streamline, Path Line, and Streak Line Static Stagnation and dynamic pressure, Unsteady Bernoulli Equation, Seminar on modern techniques of pressure measurement, Case study on Bernoulli theorem and application*	
Module-2 - Differential approach and Integral Approach	***15 Hour***
Conservation of mass-rectangular coordinate, Differential Momentum equation, Reynolds transport theorem, Fluid translation, Deformation, Vorticity and circulation, Source, sink, doublet, Laplace equation, Experiment on free and forced vortex	
Module-3 - Internal Incompressible Viscous Flow	***15 Hour***
Laminar flow, turbulent flow, fully develop laminar flow between parallel plates, Shear stress distribution, fully developed turbulent flow in pipe, Turbulent velocity profile, Energy consideration in pipe flow, Flow measurement-venturi, nozzle, Seminar on modern techniques of flow measurement	
Module-4 - External Incompressible Viscous Flow	***15 Hour***
Boundary layer concept, *Laminar flat plate boundary layer, exact solution, Pressure gradient in boundary layer flows, Relaminarization, Streamlining, Karman Vortex Street, Flow past airfoil, Case study on Flow past cylinder*	
Module-5 – Turbulence	***15 Hour***
Characteristics of turbulent flow, Kinetic Energy Budget of Mean Flow, Turbulence Production and dissipation, Correlations and Spectra, Eddy Viscosity and Mixing Length, Kolmogorov universal law, Vortex stretching, Turbulent Jets and wakes, Case study on concept of laminar-turbulent *transition in Pipe*	

Learning Resources		
Learning Resources	1. Schlichting H., K. Gersten, Boundary Layer Theory, 8/e, Springer 2000 2. N.P. Bali and Manish Goyal, A text book of Engineering Mathematics, Laxmi Publications, New Delhi, 10th edition,2016. 3. Kandasamy P., etal. Engineering Mathematics, Vol.II & Vol.III (4th revised edition), S. Chand & Co., New Delhi, 2000	4. F. M. White, Viscous Fluid Flow (3rd edition), McGraw-Hill, 2005 5. K. Muralidhar and G. Biswas, "Advanced Engineering Fluid Mechanics", 3rd Edition, Narosa Publishers, 2015 6. P. Kundu, I. Cohen and D. Dowling, Fluid Mechanics, Elsevier, 6th Edition, Academic Press, 2015.

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	-	30%	30%	-
Level 2	Understand	30%	-	-	30%	30%	-
Level 3	Apply	20%	-	-	20%	20%	-
Level 4	Analyze	20%	-	-	20%	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Parag Deshpande, senior scientist, NAL	1. Dr Aviansh Kumar, IITDM Kancheepuram	1. Dr Pankaj Kumar, SRMIST
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	2. Dr Vihnu M Teja, IIT(ISM) Dhanbad	2. Dr. Santosh Kumar Singh, SRMIST

Course Code	21MEC542J	Course Name	ADVANCED HEAT TRANSFER	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the 1-D conduction heat transfer*
CLR-2:	*understand the steady 2-D and 3-D conduction heat transfer*
CLR-3:	*understand the free and forced convection*
CLR-4:	*understand the radiation heat transfer*
CLR-5:	*understand the mass transfer principles*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*solve the steady state heat conduction for 1,2 and 3-D geometries.*	3	-	-
CO-2:	*analyze the Newton's law of cooling*	-	2	-
CO-3:	*analyze the free and forced convection heat transfer*	-	-	3
CO-4:	*calculation of heat exchange between gray surfaces*	-	3	-
CO-5:	*compute the mass transfer coefficient in diffusion and convective mass transfer*	1	-	-

Module-1 - Conduction	***15 Hour***
Equations of conduction heat transfer, Initial and boundary conditions, Effect of temperature on thermal conductivity, Practice on numerical modeling on conduction heat transfer in metals, Steady one-dimensional conduction heat transfer-A general problem and composite structures, Bessel's equation, Practice on numerical modeling on conduction in composite system, Heat transfer in extended surface, Heat transfer in extended surface with Constant Cross-Section, Heat transfer in extended surface with Variable Cross-Section, Experiment on Extended surfaces	
Module-2 - Steady 2-D and 3-D conduction	***15 Hour***
Separation of Variables, Homogeneous Problems, Practice on numerical modeling of conduction in 2-dimension, Non- Homogeneous Problems, Cylindrical Geometry Practice on numerical modeling of heat transfer in 3-dimension, Spherical Geometry, Steady 3 – Dimensional Geometry, Method of Superposition, Practice on conduction heat transfer in spherical geometry.	
Module-3- Convection	***15 Hour***
Newton's law of cooling and mechanism of convection, Type of convection, Natural convection and important non-dimensional numbers, Estimation of natural convection heat transfer co-efficient, Thermal and hydrodynamic boundary layer-natural convection, Forced convection and related non-dimensional numbers, Estimation of forced convection heat transfer co-efficient, Empirical correlation for finding heat transfer co-efficient, Combined laminar and turbulent flow, Numerical modelling on boundary layer development in pipe flow.	
Module-4 - Radiation	***15 Hour***
Basics laws of radiation heat transfer, Estimation of Stefan-Boltzmann constant, View factors calculations, Heat exchange between gray surfaces, Estimation of emissivity of the gray body, Radiation shield, Gaseous radiation, Numerical modelling on radiation heat transfer.	

Module-5 – Mass Transfer	***15 Hour***
Fick's Law of Diffusion, Convective mass transfer coefficient, Velocity, thermal and concentration boundary layers, Seminar on non-dimensional numbers related to mass transfer, Steady state molecular diffusion, Mass transfer coefficients, Dimensionless groups in mass transfer, Dimensionless groups in mass transfer, Interphase mass transfer Interphase mass transfer, Overall mass transfer coefficient, Estimation of mass transfer co-efficient	

Learning Resources	*1) F. Naterer, Greg. Advanced Heat Transfer. United States: CRC Press, 2018.* *2) Venkateshan, S.P.. Heat Transfer. Germany: Springer International Publishing, 2021* *3) Karwa, Rajendra. Heat and Mass Transfer. Germany: Springer Nature Singapore, 2020.* *4) Balaji, C.., Srinivasan, Balaji., Gedupudi, Sateesh. Heat Transfer Engineering: Fundamentals and Techniques. Netherlands: Elsevier Science, 2020.*	*5) Fundamentals of Heat and Mass Transfer, Incropera, F. P. and De Witt, D. P., 5th Edition, Wiley, Indian Edition, 2018* *6) Heat and Mass Transfer: Fundamentals and Applications, Yunus A. Çengel and Afshin Jahanshahi Ghajar, McGraw-Hill Education, 2020, 6th Edition* *7) Ozisik. M. N, "Heat Transfer", McGraw-Hill Book Co., 2003* *8) DATA BOOKS:. Kothandaraman. C. P, Subramanyan, S, "Heat and Mass Transfer Data Book", New Age International, 7th edition, 2012.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*30%*	-	-	*30%*	*30%*	-
Level 2	*Understand*	*30%*	-	-	*30%*	*30%*	-
Level 3	*Apply*	*20%*	-	-	*20%*	*20%*	-
Level 4	*Analyze*	*10%*	-	-	*10%*	*10%*	-
Level 5	*Evaluate*	*10%*	-	-	*10%*	*10%*	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Dr. Amit Gupta, ABSTC, Mumbai	*Prof. Gurveer Singh, MANIT, Bhopal*	1. *Dr. Piyush Sharma, SRMIST*

Course Code	21MEC543J	Course Name	COMPUTATIONAL FLUID DYNAMICS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*get familiarity with governing equations of fluid mechanics and their mathematical behavior*
CLR-2:	*understand the intricate details of discretization techniques and stability analysis of difference equations*
CLR-3:	*know various numerical methods to solve equations and solution technique for compressible flows*
CLR-4:	*grasp techniques for coupling continuity and momentum equations for incompressible flows, SIMPLE algorithm and its application to Couette flow*
CLR-5:	*be familiar with concepts of turbulence and its modelling*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*derive governing equations to a fluid system and classify governing equations mathematically*	*2*	*2*	-
CO-2:	*implement different discretization techniques to solve simple PDEs, and perform stability analysis*	*3*	*3*	-
CO-3:	*analyze the solution techniques for algebraic, ordinary differential and partial differential equations and applying to solve compressible flows*	*3*	*3*	-
CO-4:	*evaluate the solution techniques for elliptic equations and apply them to potential flows, incompressible flows and specifically to Couette flow*	*3*	*3*	-
CO-5:	*evaluate the concept of turbulence and Reynold's averaging and* examine the *turbulence modelling approaches*	*3*	*3*	-

Module-1 - Governing Equations	***15 Hour***
Equations Introduction, Various applications of computational fluid dynamics, Models of fluid flow, Continuity equation derivation in all forms, Momentum, Energy and Scalar transport equations derivation, Conservation and Non conservation form of governing equations, Different types of boundary conditions –Dirichlet, Neumann, Cauchy and Robbins boundary conditions with examples, Classification and Mathematical behavior of Partial differential equations – elliptic ,parabolic and hyperbolic, well posed problems. Practical- Introduction to commercial CFD software, Simulation of flow over a flat plate for laminar conditions	
Module-2 Discretization Techniques	***15 Hour***
Discretization concept and principles, Finite difference approximations of partial derivatives – Forward, Backward and Central difference methods, Discretization of one dimensional un-steady state heat conduction, Explicit and Implicit method, Discretization of one dimensional wave equation, Tutorials on discretization of equations, Stability analysis of different equations, consistency and convergence, Discussion on CFL condition, Short discussion on shock capturing methods: Godunov, TVD, flux-limiter schemes. Practical: Coding on explicit and implicit schemes and simulation of flow over circular pipe for laminar condition with commercial CFD software conditions.	
Module-3 - Solution Techniques and Numerical Methods for Compressible Flows	***15 Hour***
Direct methods for system of linear equations: Gauss elimination method and Tri-diagonal matrix algorithm (TDMA), Iterative methods: Gauss-Siedel, Jacobi and relaxation techniques, Solution techniques for ordinary differential equations: Euler, predictor-corrector, Runge-Kutta (4 stages) methods, Linear multi-step methods: Adams-Bashforth method, Short discussion on algebraic multi-grid method, Application of McCormack technique to compressible flows: case study- Supersonic flow through convergent-divergent nozzle: Governing equations, numerical method, boundary conditions,	

case set-up and results, Tutorials on McCormack method, Coding practice for Jacobi method. Practical: Coding on TDMA, and relaxation techniques, Supersonic flow simulation in a convergent-divergent nozzle with commercial CFD software	
Module-4 Solution Techniques for Elliptic and Parabolic Equations	***15 Hour***
Application of relaxation techniques to potential flow equation, Application of Alternating Direction Implicit (ADI) method to unsteady two-dimensional heat conduction, Techniques for incompressible Navier-Stokes equations: Concept of staggered grid., Pressure correction method, SIMPLE algorithm and boundary conditions, Solution of Couette flow using SIMPLE algorithm. Practical: Coding on ADI method, Grid convergence study on flat plate flow with Fluent	
Module-5 – Introduction to Turbulence Modelling	***15 Hour***
Concept of Turbulent boundary layer over a flat plate: Laminar sub, logarithmic and outer layers, Concept of turbulence, Reynolds averaging, Time averaged equations for turbulent flow, Boussinesq approximation, Types of turbulence models: Prandtl mixing length, One-equation, Two-equation models, Comparison of different turbulent models, Energy cascade mechanism in turbulent flows, Advanced methods: Large Eddy Simulations, Direct Numerical Simulations, Detached Eddy Simulations. Practical: Turbulent simulation of flow a in circular pipe, flat plate, mixing layer with k-ε model with commercial CFD sofware	

Learning Resources	*1. Anderson J.D., "Computational Fluid dynamics: The basics with Applications", McGraw Hill Education, July 2017.* *2. Versteeg H.K., and Malalasekera W., "An introduction to computational fluid dynamics"The finite volume method", Pearson India Publisher, January 2010.* *3. Muralidhar.K, and Sundararajan.T, "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, Second Edition, 2008*	*4. Erwin Kreyszig, "Advanced Engineering Mathematics", John Wiley & Sons, 2011.* *5. R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot, "Transport Phenomena", 3rd Edition, John Wiley and Sons, 2013.* *6. Piyush K. Kundu and Ira M. Cohen, "Fluid Mechanics", 4th Edition, Elsevier, 2010*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	-	30%	30%	-
Level 2	Understand	30%	-	-	30%	30%	-
Level 3	Apply	20%	-	-	20%	20%	-
Level 4	Analyze	20%	-	-	20%	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***
1. Dr. Anil Kumar, Fluidyn Consultancy Private Limited, Bengaluru.	*1.Dr. Arul Prakash, Professor, IIT Madras*	*1. Dr. D. Siva Krishna Reddy, SRMIST*
2. P. S. G. Kumar, Siemens Industry Software (India) Pvt Ltd, Bengaluru		

Course Code	21MEC541T	Course Name	MATERIALS FOR HEAT TRANSFER	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*be familiar with the materials characterization techniques*
CLR-2:	*learn the different types of materials for heat transfer*
CLR-3:	*understand the characteristics of the materials for thermal management*
CLR-4:	*understand the characteristics of the non-metal composite materials for thermal management*
CLR-5:	*learn the significance of materials for advanced thermal management*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	*2*	*3*
CO-1:	*Characterize materials for thermal management*	*1*	-	-
CO-2:	*Categorize the materials used for Thermal management*	-	*2*	-
CO-3:	*Identify suitable metal matrix composites for heat transfer*	-	-	*1*
CO-4:	*Appreciate Polymer, ceramics matrix composites for thermal management*	*3*	-	-
CO-5:	*Review the application of advanced materials for thermal management of electronic equipment*	-	-	*3*

Module-1 – Material Properties and Characterization for Thermal Management	***9 Hour***
Thermal Properties types and Measurement techniques, Thermal Conductivity and Diffusivity, Coefficient of Thermal Expansion, Specific Heat Capacity- Thermal Shock Resistance, Materials Characterization: Optical Microscopy. Scanning Electron Microscopy - Scanning Acoustic Microscopy, Atomic Force Microscopy, X-Ray Diffraction- Photoelectric Spectroscopy, UV/VIS Spectroscopy-Thermal analysis: TGA, DSC, DMA,TMA	
Module-2 – Materials Classification	***9 Hour***
Types of Materials, Methodology of Material selection for Thermal management, Metallic Materials: Silver, gold. Metal alloys, Ceramics Materials, Semi-Conductors- Silicon, Germanium, Electronic glasses, Multilayer laminates, PCB materials, Interface materials- lead, tin, Advanced thermal conductive materials.	
Module-3 – Carbon, Copper and Metal Matrix Materials, and its Composites	***9 Hour***
Carbon matrix Composites, Carbon nanotubes, Pyrolytic Graphite- Graphene, Diamond, Metal Matrix composites, Aluminum Matrix Composites- Boron, Silicon Carbide, etc, Copper matrix Composites-Graphite, Carbon nanofiber Silicon carbide, etc., Other Metal Matrix Composites. Beriyillium, Silver- Diamond	
Module-4 – Polymer, Ceramics, Interface Composites	***9 Hour***
Polymer Matrix Types: Polymer–Carbon, Polymer-Metal, Polymer-Ceramic, Polymer Matrix Nanocomposites, Reinforcements of Conductive Polymer Composites *General Fabrication and Manufacturing Processes, State of the Art in Processing of SiC Matrix Ceramic, Reaction-Bonded SiC Composites, Ceramic Nanocomposites, Ceramic Matrix Composite Thermal Protection System, Thermal Interface Materials in Electronic Packaging: Metals, Organic, Criteria for Selection of Thermal Interface Materials*	

Module-5 – Advanced Thermal Management Materials	*9 Hour*
Smart Composites, Multifunction materials, Electromagnetic Interface shielding and Absorbing materials, Embedded Droplet Impingement for Integrated Cooling of Electronics Equipment, Liquid cooling materials: PCM, Heat Spreader materials. Dielectric, Metallic and Composite, Standards and Specifications for Evaluation of Thermal Management in Electronic Industry- Life and reliability Evaluation, flammability and toxicity testing	

Learning Resources		
	1. *R. B. Bird, W. E. Stewart, E. N. Lightfoot. "Transport Phenomena", 2nd Edition, John Wiley & Sons (Asia) pvt. Ltd. 2002.* 2. *C. J. Geankoplis, "Transport Processes and Separation Process Principles", 4th Edition, PHI Learning Private Limited., New Delhi.* 3. *W. J. Thomson, "Introduction to Transport Phenomena", Prentice Hall, 2000.*	4. *S. K. Thamida, "Transport Phenomena: Chemical Processes", STUDIUM PRESS, 2019.* 5. *A. Keshav B. Mazumdar "Transport Phenomena", Willey, 2020.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Amit Gupta, ABSTC, Mumbai*	1. *Dr. Laltu Chandra, IIT Kanpur*	1. *Prof. T. Lakshmanan, SRMIST*
2. *Dr. N Saravanan, Principal Engineer, Smart Implements & Machinery and Sustainability, Mahindra*	2. *Dr. Raju Abraham Scientist NIOT, Chennai*	

ACADEMIC CURRICULA

Thermal Engineering
Specialization: Electronic Cooling/ Computational Fluid Dynamics

Professional Elective Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21MEE542T	Course Name	TRANSPORT IN POROUS MEDIA	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize with transport phenomena.*
CLR-2:	*be familiar with the time dependent flow of the Newtonian fluids*
CLR-3:	*attain the knowledge about momentum and mass transport.*
CLR-4:	*attain the knowledge about diffusion with various chemical reactions.*
CLR-5:	*calculate the pressure loss over pipe and pipeline systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	*2*	*3*
CO-1:	*understand the momentum and mass transport.*	1		-
CO-2:	*understand the concept of representative elementary volume and representative elementary area.*	-	2	-
CO-3:	*understand the concept single phase flow.*	-	-	1
CO-4:	*understand the concept single phase flow through porous media.*	3	-	-
CO-5:	*understand the concept of wettability.*	-	-	3

Module-1 – Introduction and Macroscopic Description of Porous Media	***9 Hour***
Definition of porous medium and classification of porous media, The Continuum Model of a Porous Medium, Macroscopic Values, Higher-Order Averaging, Macroscopic Description of Transport Phenomena in Porous Media, Macroscopic Boundary Conditions, Mathematical Statement of a Transport Problem.	
Module-2 – Transport Properties and Single-Phase Flow Through Porous Media	***9 Hour***
Importance of studying single-phase flow, Overview of applications, Types of porosity, Darcy's law, Assumptions and limitations, Factors affecting permeability, Temperature Effect on Permeability, Forchheimer equation, Pore Connectivity and Parametric Functions.	
Module-3 – Fluid Transport Through Porous Media	***9 Hour***
Introduction, Coupling Single-Phase Mass and Momentum Balance Equations, Cylindrical Leaky-Tank Reservoir Model Including the Non-Darcy Effect, Coupling Two-Phase Mass and Momentum Balance Equations for Immiscible Displacement, Coupling Two-Phase Mass and Momentum Balance Equations for Immiscible Displacement, Numerical Solution of Incompressible Two – Phase Fluid Displacement Including the Capillary Pressure Effect, Case study on capillary, The Buckley–Leverett Analytic Solution.	
Module-4 – Parameters of Fluid Transfer in Porous Media	***9 Hour***
Introduction, Wettability and Wettability Index, Capillary Pressure, Work of Fluid Displacement, Temperature Effect on Wettability-Related Properties of Porous Media, Direct methods for the determination of porous media flow functions and parameters, Direct Interpretation Methods for the Unsteady-State Core Tests Indirect methods for the determination of porous media flow functions and parameters, Formulation of a Two-Phase Flow in Porous Media Determination of Relative Permeability under Constant Pressure Conditions, Determination of Relative Permeability under Constant Rate Conditions	
Module-5 – Classical Theory of Diffusion and Seepage Problems in Porous Media	***9 Hour***

Seepage Problem for a Multi-component Solution in Saturated Porous Media, Navier-Stokes equation and the classical permeability theory, Fick's Law and Evaluation of the Diffusion Coefficient, Adsorption Isotherm and the Distribution Coefficient Langmuir's Equilibrium, Adsorption Isotherm, Freundlich's Equilibrium, Adsorption Isotherm, Langmuir's Non-equilibrium Adsorption Isotherm, Freundlich's Non equilibrium Adsorption Isotherm

Learning Resources	1. *R. B. Bird, W. E. Stewart, E. N. Lightfoot. "Transport Phenomena", 2nd Edition, John Wiley & Sons (Asia) pvt. Ltd. 2002.* 2. *C. J. Geankoplis, "Transport Processes and Separation Process Principles", 4th Edition, PHI Learning Private Limited., New Delhi.* 3. *W. J. Thomson, "Introduction to Transport Phenomena", Prentice Hall, 2000.*	4. *S. K. Thamida, "Transport Phenomena: Chemical Processes", STUDIUM PRESS, 2019.* 5. *A. Keshav B. Mazumdar "Transport Phenomena", Willey, 2020.* 6. *J. Bear, Y. Bachmat, "Introduction to Modeling of Transport Phenomena in Porous Media, Kluwer Academic Publisher, 1990.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Dr. Amit Gupta, ABSTC, Mumbai	*1. Prof. Ajmira Nageswara Rao*	*1. Dr. Piyush Sharma, SRMIST*

Course Code	21MEE543T	Course Name	RADIATIVE HEAT TRANSFER	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Heat and Mass transfer data book*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize with the fundamentals of thermal radiation*
CLR-2:	*understand the radiative properties of the surfaces and mediums*
CLR-3:	*familiarize with the radiation exchange*
CLR-4:	*understand the radiative heat transfer theory*
CLR-5:	*get familiar with the applications of radiative heating and cooling*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*discuss the fundamentals of thermal radiation*	2	-	3
CO-2:	*illustrate the radiative properties of surfaces and mediums*	2	-	3
CO-3:	*solve the thermal radiation exchange problems*	2	-	3
CO-4:	*explain the radiative transfer theory*	2	-	3
CO-5:	*investigate the radiative heating and cooling solutions*	2	-	3

Module-1 - Fundamentals of Thermal Radiation	***9 Hour***
Introduction and nature of radiation, Electromagnetic wave theory vs Photon theory, Planck's law of radiation, Stefan Boltzmann law of radiation, Wien's displacement law, Kirchhoff's law, Hemispherical and total emissive power, solid angle, Intensity of radiation, Entropy and exergy of radiation exchange, Case studies: Radiation exchange between Sun and Earth, and Measurement of solar radiation.	
Module-2 - Radiative Properties of Surfaces and Mediums	***9 Hour***
Black, grey and real body, Emissivity, Absorptivity, Reflectivity, and Transmissivity - Directional, hemispherical - Spectral and total. Radiative properties - opaque surfaces, transparent medium, vapor and gases. Measurement of radiative surface properties, Case studies: Spectral coating for solar heating application, Color temperature and its applications, and Influence of atmospheric emissivity on ambient temperature.	
Module-3 - Radiative Exchange	***9 Hour***
Radiation view factor, View factor algebra, Methods for evaluation of view factor- Area and contour integration, Crossed string rule. Radiative exchange between black, gray, and diffuse surfaces, Electrical network analogy, Radiation shields, Radiative exchange between partially specular surfaces. Case studies: Application of crossed string rule for performance evaluation of solar bifacial photovoltaic panels, and uses of radiation shields.	
Module-4 - Radiative Transfer Equation (RTE)	***9 Hour***
Surface to surface radiation-Discrete Ordinate method, Ray Tracing method of evaluation radiation exchange. The radiative transfer equation- Boundary conditions for the radiative transfer equation, Formal solution to the radiative transfer equation. Coupling surface-to-surface radiation with conduction and convection - Natural convection with radiation. Thin radiating fins with radiation, Radiative heat transfer coefficient.	
Module-5 – Radiative Heating and Cooling	***9 Hour***
Characteristics of solar radiation, Solar thermal collector-flat plate, concentrating collector. Radiative sky cooling-Spectral coating and applications of radiative cooling. Surface coatings for reduced heat infiltration, Application of radiative heat transfer for electronic cooling and building energy conservation. Field visit: Solar cooking plant.	

Learning Resources	1. *Modest MF, Mazumder S. Radiative heat transfer. Academic press; 2023 Oct 16.* 2. *Siegel R. Thermal radiation heat transfer. CRC press; 2021 Dec 7.*	3. *Balaji C. Essentials of radiation heat transfer. Wiley; 2014 Jul 1.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. N Saravanan, Principal Engineer, Smart Implements & Machinery and Sustainability, Mahindra*	1. *Dr. Akhilesh Arora, DTU, Delhi*	1. *Dr. S. Manikandan, SRMIST*
	2. *Dr. S. K. Tyagi, IIT Delhi*	

Course Code	21MEE544J	Course Name	COMPRESSIBLE AND INCOMPRESSIBLE FLUID FLOWS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*know the basics of the compressible and Incompressible flows*
CLR-2:	*apply the NS equations for the various flows*
CLR-3:	*know the nozzle flows and normal shock relations*
CLR-4:	*analyze the various oblique shock relations*
CLR-5:	*know the basics of shock boundary layer interactions*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand some phenomena in compressible and incompressible flows*	2	-	-
CO-2:	*solve the NS equations for various flow conditions*	-	-	2
CO-3:	*analyze the various normal shock relations for various scenarios*	-	-	2
CO-4:	*analyze the various oblique shock relations for various scenarios*	-	-	2
CO-5:	*understand some fundamentals on shock wave boundary layer interactions*	2	-	-

Module-1 - Basic Concepts in Incompressible Flows	***12 Hour***
Compressibility of fluids, Compressible and Incompressible flow, Types of flows, Vectors and Tensors, Pathlines, Streaklines and Streamlines, Case Study 1: Water tunnel study of flow around circular cylinders, Stream function, Velocity potential function, Problems on vorticity, Vorticity and Circulation, Problems on circulation, Lagrangian & Eulerian viewpoint, Case Study 2: Study of free and forced vortices, Substantial derivative, Decomposition of Motion, Rate-of-Strain Characteristics.	
Module-2 - Incompressible Navier–Stokes Equations	***12 Hour***
Stress, deformation, Control volume approach, Reynolds transport theorem, Conservation of mass, momentum and energy, Viscosity law, Case Study 3: Wind tunnel study of flow around an airfoil at low Re, Navier-Stokes equations, Exact solutions of Navier-Stokes equations, Parallel flow in straight channel, Case Study 4: Apply NS equations on your own defined flow field problem, Couette flow, Hagen–Poiseuille Flow in a Pipe, Flow Between Concentric Rotating Cylinders.	
Module-3 - Normal Shock Waves	***12 Hour***
Speed of sound, Mach number, Mach cone, Wave motion, and sonic speed, Problems on Mach number, One-dimensional flow, convergent, divergent, CD nozzle, Case Study 5: Numerical study of flow through CD nozzles at subsonic speeds, Maximum achievable velocity of a gas, Isentropic flow Mach number relationships, Formation of compressible and expansion waves, Normal shock relationship, temperature ratio, Pressure ratio, Density ratio, Case Study 6: Numerical study of flow through CD nozzles at supersonic speeds, Mach number downstream of the normal shock, Entropy changes across the shock, Prandtl- Meyer relations, Rankine – Hugoniot equations, Normal shock in a CD nozzle.	
Module-4 - Oblique Shock Waves	***12 Hour***
Supersonic flow over a concave & convex corner, Source of Oblique Shock Waves, Oblique shock wave relations, Density ratio, Pressure ratio, Temperature ratio, Mach number relations, Case Study 7: Experimental flow features study of free jet at subsonic speeds, θ-β-M relations, Attached, detached shock waves, Weak and strong shocks, Supersonic flow over wedges and cones, Case Study 8: Experimental flow features study of free jet at supersonic speeds, Shock polar, Reflection of oblique shock waves, Interaction of oblique shock waves, Prandtl Mayer expansion waves, Prandtl Mayer functions.	
Module-5 –Shock Wave-Boundary Layer Interactions	***12 Hour***

Shock Wave–Boundary-Layer Interactions and its Importance, Discontinuities in Supersonic Flows, Boundary-Layer Response to a Rapid Pressure Variation, Case Study 9: Boundary layer study of flow over a various object, Interactions without Separation, Incident Reflecting Shock, Ramp-Induced Shock, Normal Shock and Transonic Interactions, Interactions with Separation, Separation Caused by an Incident Shock, Ramp-Induced Separation, Case Study 10: Review paper on numerical study of a shock-wave boundary-layer interaction, Normal Shock-Induced Separation/ Transonic Separation, Transitional SBLIs, Separation in Supersonic-Flow and Free-Interaction Processes, SBLI Control Techniques.

Learning Resources	1. *Cengel, Y. and Cimbala, J., 2013. Fluid mechanics fundamentals and applications (SI units). McGraw Hill.* 1. *Panton, R.L., 2013. Incompressible flow. John Wiley & Sons* 2. *V. Babu., 2016. Fundamentals of Incompressible Fluid Flow - Ane Books Pvt. Ltd* 3. *Anderson, J.D., 1990. Modern compressible flow: with historical perspective (Vol. 12). New York: McGraw-Hill.*	4. *Zucker, R.D. and Biblarz, O., 2019. Fundamentals of Gas Dynamics. John Wiley & Sons.* 5. *E. Rathakrishnan., 2017. Gas Dynamics. Prentice-Hall of India Pvt.Ltd* 6. *Babinsky, H. and Harvey, J.K. eds., 2011. Shock Wave-Boundary-Layer Interactions (Vol. 32). Cambridge University Press.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	-	30%	30%	-
Level 2	Understand	30%	-	-	30%	30%	-
Level 3	Apply	20%	-	-	20%	20%	-
Level 4	Analyze	20%	-	-	20%	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Gireesh Yanamashetti, National Aerospace, Laboratory, Bangalore*	1. *Dr V. Babu, Professor, IIT Madras*	1. *Dr. P. Balakrishnan, SRMIST*
2. *Dr. G. Muthu Selvan, NAL, Bangalore*	2. *Dr.S.Mohammed Ibrahim, IITKanpur*	2. *Dr. Gunasekaran, SRMIST*

Course Code	21MEE544T	Course Name	MICRO AND NANOSCALE HEAT TRANSFER AND FLUID FLOW	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*gain the knowledge on basics of micro and nanoscale heat transfer and fluid flow*
CLR-2:	*familiarize with fundamental elements of solid-state physics and quantum mechanics*
CLR-3:	*gain the knowledge on micro and nanoscale conduction heat transfer*
CLR-4:	*gain the knowledge on micro and nanoscale convection heat transfer*
CLR-5:	*familiarize with microfluidics and applications of microfluidics/nanofluids*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	2	3
CO-1:	*describe the recent developments heat transfer and fluid flow with micro/nanoscale technologies.*	*3*	*-*	*-*
CO-2:	*describe the solid-state physics and quantum mechanics with micro/nano scale fluid flow*	*3*	*2*	*-*
CO-3:	*analyze the micro and nanoscale conduction heat transfer*	*3*	*2*	*-*
CO-4:	*evaluate the micro and nanoscale convection heat transfer*	*3*	*2*	*-*
CO-5:	*identify the use of micro and nano technologies for the various heat transfer and fluid flow applications*	*3*	*2*	*-*

Module-1 - Overview of Microscale & Nanoscale Heat Transfer and Fluid Flow	***9 Hour***
Introduction to materials and their properties, Types of micro and nano materials, Basics of microscale and nanoscale transport - Principles of microfluidics and nanofluids, Preparation, Basic phenomenon of conductive heat transfer in micro and nano scale - Basic phenomenon of convective heat transport in micro and nano scale, Case study: Recent trends on microfluidics - Heat transfer and fluid flow mechanisms on micro and nano scale surfaces, Micro and nano scale engineering Applications- micro channels, micro heat pipes, thin films, Electronics cooling with micro and nano scale materials - Micro and nanoscale two phase flow heat transfer, radiation heat transfer - Case study: Recent trends on nanofluids, Micro and nano scale radiation heat Transfer - Heat transfer and fluid flow mechanisms on micro and nano scale surfaces, Micro and nano scale engineering Applications - micro channels, micro heat pipes, thin films, Demonstration on preparation and characterization of nanofluids.	
Module-2 - Fundamental Approaches for Micro and Nanoscale Fluid Flow	***9 Hour***
Fundamentals of micro and nano scale fluid mechanics, limitations of macroscopic formulations size effect behaviour, microscopic view point - Basic aspects of quantum mechanics, Basics of kinetic theory and statistical mechanics - Case study on micro and nano scale behavior on fluid flow (cont.), Maxwell's equation, Maxwell's slip theory, Molecular dynamics modelling - Density of micro and nano scale materials, Density of microfluids, Density of nanofluids, density models, Viscosity of microfluids and nanofluids - Case study on micro and nano scale behavior on fluid flow, Viscosity models and importance - Knudsen number, Flow regimes, Density and viscosity on pressure drop - Tutorial- Experimental validation of viscosity and density of microfluidics and nanofluids with existing correlations	
Module-3 - Micro and Nanoscale Heat Conduction	***9 Hour***
Thermodynamic relations, Boltzmann transport equation, Van der Waals potential, Classical laws - Fourier, Newton, Ohm, thermoelectric effect, Micro and nano scale heat conduction - basics of electron and phonon transport, Demo Measurement of thermophysical properties of micro and nanofluids (cont.) - Thermal conductivity and Specific heat capacity of micro and nano materials - Thermal conductivity and Specific heat capacity of nanofluids and microfluidics - Thermal conductivity and specific heat capacity models, Conduction in thin films - Tutorial on establishment of new correlation for measured thermophysical properties of fluids - semiconductors, electronic devices - Landauer formalism, Bose-Einstein and Fermi-Dirac equilibrium distributions - Optimization of thermophysical properties of fluids	

Module-4 - Micro and Nanoscale Convection	***9 Hour***
Hydrodynamic and thermal boundary Layer, Principles and governing equations - Hydrodynamic and thermal boundary Layer, Principles and governing equations - Convective heat transfer with micro and nano materials - Theatrical study on thermal properties of microfluidics and nanofluids, Governing equations, Single phase forced connection - Convection in circular tube, Basic theory of convective heat transfer enhancement with nanoparticles - Convection in mini and /micro channels, Analysis on effect of thermophysical properties on convective heat transfer coefficient of micro and nanofluids - Thermal properties of Nanofluids on convective heat transfer, Transport phenomenon in nanoparticle suspensions - applications of nanofluids and microfluidics - Numerical investigation on flow behavior of micro and nano fluids subjected to constant heat flux.	
Module-5 – Micro and Nanofluids - Applications	***9 Hour***
Fundamentals of Electro kinetics, Low inertia flows, Electrokinetic, Micro mixing, surface wettability - Pressure-driven, surface tension driven flows, Microfluidics devices, micro pumps, micro mixing, actuators - A case study on Selection of nano blended phase change materials and its micro and nanofluidic applications - Selection of nanofluids for various heat transfer applications - Selection of phase change materials for thermal energy storage, Nano enhanced phase change materials for thermal energy storage applications - Usage of nano-enhanced phase change materials and nanofluids for various applications- case study Applications in heat Transfer with micro and nano scale materials - Micro and nano scale data measurements, Engineering Applications for micro and nano scale - Tutorial – Literature review on micro and nanofluidic applications such as lab on chips and micro electro mechanical systems (MEMS).	

Learning Resources	1. *Zhuomin M. Zhang, Nano / Microscale Heat Transfer, Mcgraw Hill, 2007.* 2. *Mourad Rebay, Sadik Kakaç, Renato M. Cotta, Microscale and Nanoscale Heat Transfer Analysis, Design, and Application, CRC press, 2016* 3. *D.Y. Tzou., Macro to Microscale Heat Transfer: The Lagging behaviour, Taylor & Francis, 1997* 4. *Pradipata kumar panigrahi, Transport Phenomena in Microfluidic Systems, 2005* 5. *S. Kakac, L.L. Vasiliev, Y. Bayazitoglu, Y. Yener., Microscale Heat Transfer, Fundamental and Applications, Springer, 2005.*	6. *Latif M. Jiji, Heat Conduction, 3rd edn., Springer, 2009.* 7. *Chen, G., “Nanoscale energy transport and conversion”, 1st edition, Oxford University Press. 2005.* 8. *C.B Sobhan and G.P Peterson, Microscale and Nanoscale Heat Transfer, CRC press, 2008* 9. *M. Faghri and B. Sunden (Eds.), Heat and Fluid Flow in Microscale and Nanoscale Structures, WIT Press, Southampton, 2004* 10. *S.K Das, S.V Choi, W.Yu and T.Pradeep, Nanofluids: Science and Technology Ist Edition, John Wiley & Sons, 2007*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Narasimman.B, Deputy Manager, Project Execution (Non-Food), Vithal Udyognagar - 388 121, Gujarat, India.*	1. *Dr. Sendhil Kumar Natarajan, Associate Professor, Department of Mechanical Engineering, National Institute of Technology Puducherry, Karaikal-609609.*	1. *Dr. C. Selvam, SRMIST.*
2. *Dr. N Saravanan, Principal Engineer, Smart Implements & Machinery and Sustainability, Mahindra.*	2. *Dr. Raju Abraham, Scientist NIOT, Chennai.*	

Course Code	21MEE545J	Course Name	THERMAL DESIGN FOR ELECTRONIC EQUIPMENT	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Heat and Mass transfer data book*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize with the fundamentals of microchannel cooling*
CLR-2:	*understand the operation of phase change materials*
CLR-3:	*familiarize with the operation of jet impingement*
CLR-4:	*understand the working of spray cooling*
CLR-5:	*get familiar with the design of hybrid thermal design*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*discuss the fundamentals of microchannel cooling*	2	-	3
CO-2:	*explain the operation of phase change materials and their uses in electronic cooling*	2	-	3
CO-3:	*illustrate the operation of jet impingement for thermal management of high-power electronics*	2	-	3
CO-4:	*discuss the working of spray cooling for thermal management of electronics*	2	-	3
CO-5:	*design hybrid thermal management systems for electronics*	2	-	3

Module-1 – Microchannel Heat Sink	***12 Hour***
Microchannel: introduction, configuration, inlet flow modification, topology optimization, Channel inlet flow modification. Microchannel branching, Micro fin and pin fin configurations, Array of flow obstructions, cold plate heat sink, Insertion of structured metal foam. Practice: Design of Micro channel heat sinks, flow simulations and thermal design of micro channel heat sink.	
Module-2 – Phase Change Materials (PCM) for Thermal Management	***12 Hour***
Immersion cooling, phase change behavior and process, selection of phase change materials for electronic cooling, novel conductive structures in PCM based heat sinks, using multiple PCMs in PCM based heat sink, PCM with partially filled copper foam, PCM – based heat sink in the presence of fins with alternate air – PCM cavities. Practice: thermal modeling and analysis of PCM filled heat sink.	
Module-3 – Jet Impingement Cooling	***12 Hour***
Jet impingement cooling of high-power electronics, principle of operation, thermal resistance network, Direct liquid jet impingement, Normal liquid jet impingement, nozzles for jet impingement, High Density Datacenter Cooling, Direct impingement immersed jet cooling, single jet and multiple jets. Practice: thermal design and analysis of jet impingement cooling.	
Module-4 – Spray Cooling	***12 Hour***
Principle and operation of Spray cooling, comparison between jet impingement and spray cooling, thermal resistance network of spray cooling. Single and Multi – nozzle spray cooling array as thermal management solution for electronics, Working fluids for spray cooling. Practice: thermal design and analysis of spray cooling.	
Module-5 – Hybrid Thermal Management Techniques	***12 Hour***
Hybrid heat sink, Hybrid heat sink in combination with phase change, jet impingement, microchannels and dimpled surface modification, heat pipe heat sinks, Hybrid cold plate design, thermoelectric cooling, thermoelectric cooling with cold plate. Case study: Thermal design and analysis of hybrid thermal management systems.	

Learning Resources		
Learning Resources	1. F. P. McCluskey, T. Podlesak, and R. Grzybowski, High Temperature Electronics. Boca Raton, FL, USA: CRC Press, 2018. 2. T. L. Bergman, F. P. Incropera, D. P. DeWitt, and A. S. Lavine, Fundamen-tals of Heat and Mass Transfer. Hoboken, NJ, USA: Wiley, 2011. 3. X. Gao and R. Li, ``Spray impingement cooling: The state of the art,'' in Advanced Cooling Technologies and Applications. London, U.K.: IntechOpen, 2018.	4. T. P. Cotter, Theory of Heat Pipes. Berkeley, CA, USA: Los Alamos Sci. Lab., Univ. California, Berkeley, 1965. 5. HoSung Lee, Thermal Design, John Wiley & Sons, Inc. 2010. 6. Safa Kasap, Peter Capper, Handbook of Electronic and Photonic Materials, Springer, 2017. 7. Ralph Remsburg, Advanced Thermal Design of Electronic Equipment, Springer, 1998

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	-	30%	30%	-
Level 2	Understand	30%	-	-	30%	30%	-
Level 3	Apply	20%	-	-	20%	20%	-
Level 4	Analyze	20%	-	-	20%	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. N Saravanan, Principal Engineer, Smart Implements & Machinery and Sustainability, Mahindra	1. Dr. Akhilesh Arora, DTU, Delhi	1. Prof. B. K. Gnanavel, SRM IST
	2. Dr. S. K. Tyagi, IIT Delhi	2. Dr. S. Manikandan, SRMIST

Course Code	21MEE545T	Course Name	INTRODUCTION TO TURBULENCE	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*classify the turbulent nature of flow*
CLR-2:	*examine statistical description of turbulence*
CLR-3:	*describe governing equation in turbulent flow*
CLR-4:	*examine free and wall-bounded flow*
CLR-5:	*be familiar with modelling and simulation of turbulent flows*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*illustrate the statistical nature and applications of turbulence flow*	3	-	-
CO-2:	*apply the statistical methods in turbulent flow.*	3	-	-
CO-3:	*analyze the Reynolds averaged Navier-Stokes (RANS) equations*	3	-	-
CO-4:	*explain free and wall bounded flow*	3	-	-
CO-5:	*categorize different turbulence modelling techniques*	3	-	-

Module-1 - Characteristics of Turbulence	***9 Hour***
Laminar and turbulent flow, Origin of turbulence, Laminar-turbulent transition, Experiment of Taylor, Benard Laminar and turbulent boundary layer, Time and Length scales in turbulent flow, Eddy motion, Wall turbulence, turbulent flows in industrial applications.	
Module-2 - Statistical description of turbulence	***9 Hour***
Random nature of turbulence, Probability distribution, averaging, Root mean square velocity fluctuations, Correlation Functions, Fourier-series representation, Kinetic energy of Fourier modes Velocity spectra, , Kolmogorov spectra	
Module-3 -Governing equation of turbulent transport	***9 Hour***
Continuum hypothesis, Continuity, Momentum and Scalar transport equation, Vorticity dynamics, Reynolds decomposition, turbulent viscosity hypothesis, turbulent production and dissipation, Steady and unsteady motion in turbulent flow	
Module-4 - Free-shear and Wall-bounded flows	***9 Hour***
Free shear flows, Plane turbulent free jet, Experimental observations, Equations of motions, Integral momentum equation, Similarity analysis of the equation of motion, Log-law, Wall region and different layers, Velocity defect law, turbulent flow in pipe	
Module-5 – Modelling and Simulation of turbulent flow	***9 Hour***
History of turbulence modelling, Reynolds averaged Navier-Stokes Equations, Closure problem, Application of turbulent models to wall-bounded flow, Direct Numerical Simulation; Large Eddy simulation, Turbulence modelling for compressible flow	

Learning Resources	1. *Turbulent Flows, Stephen B. Pope, Cambridge University Press, 2009* 2. *A First Course in Turbulence, Hendrik Tennekes and John L. Lumley, MIT Press 2018*	3. *Turbulent flows: Fundamentals, experiments and modeling, Biswas, G., and V. Eswaran, eds.,CRC Press, 2002* 4. *Turbulence: An Introduction for Scientists and Engineers, Peter Davidson, Cambridge University Press, Oxford University Press; 2015, Second Edition.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1) Dr. Parag Deshpande, Senior Scientist, NAL	1) Dr Aviansh Kumar IITDM Kancheepuram	1) Dr Pankaj Kumar, SRMIST
2) Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	2) Dr Vihnu M Teja IIT ISM Dhanbad	2) Dr. Santosh Kumar Singh, SRMIST

Course Code	21MEE546J	Course Name	HEAT TRANSFER IN ELECTRONIC SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*gain the knowledge on basics of machine learning for physical modelling*
CLR-2:	*familiarize with the machine learning in experimental thermal science*
CLR-3:	*gain the knowledge on direct cooling methods with machine learning for electronic cooling*
CLR-4:	*gain the knowledge on indirect cooling methods with machine learning for electronic cooling*
CLR-5:	*familiarize with hybrid cooling methods using machine learning for electronic cooling*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*describe the recent developments on machine learning for physical modelling.*	3	1	-
CO-2:	*describe the machine learning in experimental thermal science*	2	3	-
CO-3:	analyze the *direct cooling methods with machine learning for electronic cooling applications*	2	3	-
CO-4:	analyze the *indirect cooling methods with machine learning for electronic cooling applications*	2	3	-
CO-5:	*identify the hybrid cooling methods using machine learning for electronic cooling applications*	2	3	-

Module-1 – Overview of Machine Learning for Physical Modelling	***12 Hour***
Machine Learning (ML) for Physical Modeling, Overview of ML algorithms and metrics - Supervised Learning Methods, Introduction to Artificial Neural Networks (ANN) using Jupyter Notebooks - Recent advances in machine learning for heat transfer - Modeling heat transfer in solids - Modeling single phase fluid flow and heat transfer - Autoregressive models (autoregressive moving average, Arima) - Modeling gas–liquid fluid flow and heat transfer - Flow regime classification, two phase pressure drops modeling - Pool boiling, internal flow boiling and condensation, Convolutional Neural Networks.	
Module-2 -Machine Learning in Experimental Thermal Science	***12 Hour***
Deep learning predicts boiling Heat transfer, Machine learning classification of Boiling regimes with low speed, direct and indirect visualization - Oil-in-water two-phase flow pattern identification from experimental snapshots using convolutional neural network - Computer Vision Models using Jupyter - Visualization-based nucleate boiling Heat flux quantification using machine learning - Visualization-based nucleate boiling Heat flux quantification using machine learning - Comparison of artificial neural networks and expert systems applied to flow pattern - Principal Component Analysis Combination of optical probe data and Machine learning technique Two- phase flow regime identification based on the liquid-phase velocity information and machine learning - Deep learning the sound of boiling for advance prediction of boiling crisis Least absolute shrinkage And selection operator regression linear discriminant analysis.	
Module-3 - Direct Cooling	***12 Hour***
A minimum specification of air-cooling with layout design by efficient optimization scheme for outline design stage - Liquid cooling practice on Meta's AI training platform - Multi-objective placement optimization of power electronic devices on liquid cooled heat sinks - Sequence Modeling - Machine learning applications for data center optimization - Psychrometric bin analysis for data Center cooling modes using artificial neural networks - Artificial neural network based prediction of temperature and flow profile in data centers - Generalized Linear Models, Liquid cooling practice on meta's AI training platform - Multi-objective placement optimization of power electronic devices on liquid cooled heat sinks - Jet impingement, ML Models for Classification.	
Module-4 - Indirect Cooling	***12 Hour***
Cold plate design for optimal thermal performance of high speed electronics, Supervised learning based power management for multicore processors - Supervised learning based power management for Multicore processors - Supervised learning based power management for Multicore processors - Predicting interfacial thermal resistance by machine learning - Reinforcement learning based self-adaptive voltage-swing adjustment of 2.5D I/Os for many core microprocessor and memory communication - Neural network-based bin analysis for indirect/direct evaporative cooling of modular data centers, Thermal modeling of data centers for control and energy usage optimization - Artificial neural network based prediction of temperature and flow profile in data centers, Neural network-based	

bin analysis for indirect/direct evaporative cooling Of modular data centers - Thermal modeling of data centers for control and energy usage optimization - Artificial neural network based Prediction of temperature and flow profile in data centers.
Module-5 - Hybrid Cooling **12 Hour**
Multi-objective placement optimization of power electronic devices on liquid cooled heat sinks, Machine learning-based heat sink optimization model for single-phase immersion cooling. Forecasting power efficiency related key performance indicators for Modern data centers using LSTMS - Emerging challenges and materials for Thermal management of electronics - A deep neural network based approach to energy efficiency analysis for cloud data center - A gray-box model for real-time transient temperature predictions in data centers - Thermal management and thermomechanical optimization at higher temperatures - Physics-informed neural networks for heat transfer problems - Artificial intelligence for power electronics in electric vehicles: challenges and opportunities, Integration of data science into thermal fluids engineering education - Recent trends in artificial intelligence-inspired electronic thermal management, Optimal regularization methods for inverse heat transfer problems.

Learning Resources	1. *Mohri, M., Rostamizadeh, A., and Talwalkar, A., Foundations of Machine Learning, MIT Press, Cambridge, MA., 2018.* 2. *Ghiaasiaan, S. M., Two-Phase Flow, Boiling, and Condensation: In Conventional and Miniature Systems, Cambridge University Press, Cambridge, UK, 2007.* 3. *Lian-Tuu Yeh, Thermal Design of Liquid Cooled Microelectronic Equipment, ASME Press, 2019.*	4. *Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2022.* 5. *Goodfellow, I., Bengio, Y., & Courville, A. "Deep Learning." MIT Press, 2016* 6. *Frank P. Incropera and David P. DeWitt, Introduction to Heat Transfer, Wiley India Edition, 2018.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	-	30%	30%	-
Level 2	Understand	30%	-	-	30%	30%	-
Level 3	Apply	20%	-	-	20%	20%	-
Level 4	Analyze	20%	-	-	20%	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Prabhakar Subrahmanym, Intel Corporation, USA*	1. *Dr. Raju Abraham Scientist NIOT, Chennai*	*1.Prof. B. K. Gnanavel, SRMIST*
2. *Dr. N Saravanan, Principal Engineer, Smart Implements & Machinery and Sustainability, Mahindra*	2. *Dr. Pandiyarasan Veluswamy, IITM*	*2. Dr. C. Selvam, SRMIST*

Course Code	21MEE546T	Course Name	POWER ELECTRONICS DESIGN FUNDAMENTALS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize with the fundamentals of power electronics*
CLR-2:	*understand the design and working of DC/DC converters*
CLR-3:	*familiarize with the operation of AC/DC converters*
CLR-4:	*understand the design and working of DC/AC inverters*
CLR-5:	*get familiar with the thermal design of power electronic devices*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*discuss the fundamentals of power electronics*	2	1	3
CO-2:	*explain the design and working of DC/DC converters*	2	-	3
CO-3:	*illustrate the operation of AC/DC converters*	2	-	3
CO-4:	*discuss the design and working of DC/AC inverters*	2	1	3
CO-5:	*examine the thermal design of power electronic devices*	2	1	3

Module-1 - Introduction to Power Electronics	***9 Hour***
Introduction to power electronics, Review of basic electrical circuits and magnetic concepts, Scope and application of power electronics, Power electronics vs. linear electronics, Power semiconductor switches- Diode, MOSFET, IGBT. Desired Characteristics in Controllable Switches, switching characteristics, Literature review: Decoding the datasheet of the power electronic switch.	
Module-2 - Design of DC/DC Converters	***9 Hour***
Design of- Step down converter (Buck), Step up converter (Boost), Buck-Boost converter, SEPIC Converter, Full bridge DC-DC converter, Flyback converter. Comparison of DC/DC convertors. Case study: Design of solar powered LED street lighting circuit using appropriate software, Design of solar photovoltaic IV curve tracer using appropriate software.	
Module-3 - Design of AC/DC Converters	***9 Hour***
Basic Rectifier Concepts, Single-phase diode bridge rectifiers (uncontrolled), Three-phase: full-bridge rectifiers (uncontrolled), Thyristor circuits and their control, Continuous and discontinuous conduction mode, Single-phase converters (controlled), Three-phase converters (controlled), Design of gate driver circuits, Over-current and overvoltage protection through snubber design. Case study: Electric vehicle charging using grid electricity.	
Module-4 - Design of DC/AC Inverters	***9 Hour***
Inductor and transformer design principles, Pulse width modulation, Design of - Single phase inverter, three phase inverter. Single phase current source inverter, Single phase voltage source inverter, Resonant Converters, Zero voltage switching and zero current switching, Design of solar micro inverter, Case study: Visit to solar photovoltaic power plant, Solar microinverter for bifacial photovoltaic panels.	
Module-5 – Thermal Design Considerations	***9 Hour***
Losses in power electronic devices, Efficiency of - DC/DC converters, AC/DC and DC/AC inverters. Thermal design consideration of power electronic devices, Junction temperature evaluation of power electronic devices, Heat sink design and selection, Reliability theory, Failure rate of power electronic components, Reliability of power electronic converter using MIL Handbook, Case Study: Reliability calculation of solar microinverter using MIL handbook.	

Learning Resources	1. *R. W. Erickson, D. Maksimovic, Fundamentals of Power Electronics, Kluwer, Academic Publishers, 2nd ed., 2001.* 2. *N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications, and Design, John Wiley & Sons, 3rd ed., 2007.*	*3. M. H. Rashid, Power Electronics: Circuits,Devices and Applications , Pearson Education India, 4th ed., 2017*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Vasudevan. B, Siemens Ltd., Bangalore	*1. Dr. Chandrasekaran S, NIT Hamirpur, Himachal Pradesh*	1. *Dr. S. Manikandan, SRMIST*

Course Code	21MEE547J	Course Name	HIGH PERFORMANCE COMPUTING IN CFD	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	20MEC543J	Co-requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Mechanical Engineering	Data Book / Codes/Standards	Nil		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*get familiarity with basics of parallel architecture*
CLR-2 :	*understand the basic principles of parallel algorithms*
CLR-3 :	*know the implementation details of parallel programming with MPI*
CLR-4 :	*grasp the concepts of parallel computing to parallelize linear solvers.*
CLR-5 :	*be familiar with concepts of parallel computing with GPUs*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CLO-1 :	*analyse the basic concepts of parallel architecture*	1	3	-
CLO-2 :	*evaluate principles of parallel algorithm design*	1	3	-
CLO-3 :	*analyze the parallel programming concepts with MPI*	1	3	-
CLO-4 :	*implement parallel algorithms with MPI in linear solvers*	-	2	3
CLO-5 :	*analyse the basic concepts GPU and practice parallel programming with CUDA*	-	2	3

Module-1 - Parallel Architecture	***12 Hour***
*History of parallel computation**,** Inter connection networks, Processor Arrays, Processor interconnection network, Multi processors**,** Distributed multiprocessors, Multicomputer, Flynn's Taxonomy, Practical: C-programming practice on data types, control statements and functions., Arrays, pointers, file input and output, Matrix addition and multiplication*	
Module-2 - Parallel Algorithm Design	***12 Hour***
Data dependence graphs and Parallelism, Data clustering, the task/channel model, Foster's design methodology: Partitioning, Communication, Agglomeration, Foster's design methodology: mapping, Case study: Boundary value problem, Adding data input, ***Practical:*** *CFD Coding practice (serial programming) on explicit method for unsteady heat conduction, implicit method for unsteady heat conduction, 2 D steady state heat conduction.*	
Module-3 - Parallel Programming with MPI	***12 Hour***
Introduction to Message Passing Interface (MPI), The message passing model, the message passing interface, MPI functions, Collective communication, Benchmarking parallel performance: Wall clock time, Load balancing and scheduling in HPC systems, Limitations of HPC: Bandwidth and latency. Practical: Coding practice on basic functions of parallel computing concepts, Coding practice on parallelization of explicit solver for unsteady heat conduction, Coding practice on parallelization of boundary value problem.	
Module-4 - Linear Solvers	***12 Hour***
Matrix multiplication with row wise block striped decomposition method, Row oriented parallel algorithm for back substitution, Row oriented parallel algorithm for Gauss elimination, Parallel algorithm for Jacobi method, Discretization of 2 D heat conduction, Serial program for 2 D heat conduction, Parallel program for 2 D heat conduction with Jacobi method, ***Practical:*** *Implementation of parallel algorithm for matrix multiplication, parallel algorithm for Jacobi method, parallelization of implicit solver for 1 D unsteady heat conduction*	
Module-5 – Parallel programming with GPU	***12 Hour***

PC architecture and Graphic Processor Unit (GPU) hardware, Threads, Blocks, grids and warps, GPU memory: Caches, Register, GPU memory: Shared, Constant and Global, Computer Unified Device Architecture (CUDA) – Basics, Brief details of CPU and GPU chip design, Air and liquid cooling of GPU cards, Short discussion on grid computing in CFD, ***Practical:*** *Parallelization of 1 D Mac-Cormack solver to compute supersonic flow field in a convergent-divergent nozzle, Coding practice with CUDA: Addition of vectors, Coding practice with CUDA: Explicit solver for unsteady heat conduction*

Learning Resources	***1.*** *Quinn, M.J., "Parallel Programming in C with MPI and OpenMP", McGraw Hill Publications, 1st Editions, 2004.* *2. Hager, G., Wellein, G., " Introduction to High Performance Computing for Scientists and Engineers, Chapman & Hall / CRC Computational Science series, 2011.* *3. Kumar, V., Grama, A., Gupta, A., Karypis. G., "Introduction to Parallel Computing", 2nd edition, Pearson India Publications, 2003*	*4. Cook, S., "CUDA Programming A Developers Guide to Parallel Computing with GPUs, "Elsevier Publications, 2013* *5. John L. Hennessy, J.L., Patterson, A.D., "Computer Architecture: A Quantitative Approach," 5th Edition, Elsevier India Pvt. Ltd. 2011* *6. CUDA C++ Programming Guide, and CUDA C++ Best Practices Guide, Release 12.2, NVIDIA, June 2023*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*30%*	-	-	*30%*	*30%*	-
Level 2	*Understand*	*30%*	-	-	*30%*	*30%*	-
Level 3	*Apply*	*20%*	-	-	*20%*	*20%*	-
Level 4	*Analyze*	*20%*	-	-	*20%*	*20%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. P. Subrahmanyam, Scientist, Intel Corporation, USA	*1. Prof. Somnath Roy, Associate Professor, IIT Kharagpur*	*Dr D. Siva Krishna Reddy, SRMIST*
2. Dr. Anil Kumar, Fluidyn Consultancy Private Limited, Bengaluru.	*2. Prof. Yogesh Bhumkar, Associate Professor, IIT Bhubaneswar*	

Course Code	21MEE547T	Course Name	INTRODUCTION TO MULTIPHASE FLOWS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the fundamentals of multiphase flow and modelling strategies*
CLR-2:	*identify interfacial instabilities and flow regimes*
CLR-3:	*predict void fraction and pressure drop—empirical methods*
CLR-4:	*understand complex multiphase systems*
CLR-5:	*learn measurement techniques and instrumentation used in multiphase flows*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*describe the most important phenomena and principles of two-phase flow in engineering applications.*	1	-	-
CO-2:	*explain the main points of boiling and condensation, heat transfer, and their enhancement methods.*	1	2	-
CO-3:	*describe the concept of boiling crisis (e.g., DNB - a departure from nucleate boiling, and dry out) and its modeling.*	1	2	-
CO-4:	*apply the basic two-phase models and flow pattern maps to calculate the pressure drops of two-phase flow at various conditions.*	1	-	3
CO-5:	*apply the models of critical flow and flooding to analyze the limiting flow of engineering processes.*	1	-	3

Module-1 - Introduction of Multiphase Flow	***9 Hour***
Introduction of Multiphase flows, Fundamental characteristics of multiphase flows, Conservation laws-mass, momentum, and energy, Laminar and turbulent flows, Interaction with the turbulence of multiphase flows, Single and multiphase flow regimes, Averaging in multiphase flows, Void fractions and their measurement, Phase flow rates and quality	
Module-2 - Flow Pattern Maps and Regime	***9 Hour***
Flow-pattern map for fluid-fluid (gas-liquid and liquid-liquid), Flow regime map for fluid-solids flows, Governing equation of gas-liquid two-phase flows, Flow patterns in vertical and horizontal co-current flow, Empirical flow regime maps and Analytical Treatment of Flow Pattern Transitions, Transitions in Horizontal Flow, Flow Regime Maps Based on Transition Criteria: The Dukler-Taitel-Barnea Work, The DTB Map and Unified Model for the Whole Range of Inclinations, Flow Regime Maps and Transition Criteria for Vertical Upwards Flow	
Module-3 - Modelling Methods for Multiphase Flow	***9 Hour***
Modelling strategies and their analysis, the empirical approach and phenomenological modelling, Multi-fluid models and one-dimensional conservation equations, Homogenous flow model (mixture and volume of fluid method), Non-homogeneous models (Eulerian model), Separated flow models, Theory of drift flux model, The Drift-Flux Model and its application, Modelling Methods for Multiphase Flows: Mixture Model, Euler-Euler Model and Euler-Lagrangian Model	
Module-4 Multiphase Flow with Systems	***9 Hour***
Multiphase flow and transport of fluids, Suspension of particles in fluids, Characterization of multiphase flow with respect to heat, mass, and momentum transfer, Packed bed and fluidized bed Transport phenomena and multiphase reactor, Gas bubble-liquid-particle interactions, Centrifugal atomization, Pressure Drop Work for Large and Inclined Pipes Used in the Oil-and-Gas Industry Two-Phase Pressure Drop in Singularities	
Module-5 Multiphase Flow with Phase Change Heat Transfer	***9 Hour***

An Introduction to Boiling Heat Transfer, Nucleation and Dynamics of Single Bubbles- Cycle of Bubble Growth and Departure, Heat Transfer in Different Regimes of Boiling, Basic principles of film and dropwise condensation, Analysis of film and dropwise condensation, Condensation heat enhancement, Measurement Techniques for Two-Phase flow Parameters - Void Fraction Measurement, Measurement Techniques for Two-Phase flow Parameters, Numerical Simulations for Two-Phase Flows with Phase change

Learning Resources	*1. John R Thome, "Encyclopedia of Two-Phase Heat Transfer and Flow III- Macro and Micro Flow Boiling and Numerical Modeling Fundamentals", World Scientific Publishing, 2018.* *2. George Yadigaroglu, Geoffrey F. Hewitt, "Introduction to Multiphase Flow- Basic Concepts, Applications and Modelling", Springer, 2018.* *3. N.I. Kolev, "Multiphase Flow Dynamics 1: Fundamentals", Springer, 2007*	*4. Wallis, "One Dimensional Two-phase flow", McGraw Hill Book Company,1st ed., USA, 2000.* *5. Clement K. S., "Two Phase Flow – Theory and Applications", 1st ed., Taylor and Francis, USA, 2003* *6. C. E. Brennen, "Fundamentals of multiphase flow", Cambridge University Press, 2005.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Shaji Sidney, Research and Development, Tan90 Thermal Solution Private Limited, 600 097, Chennai, India, Email: shajisidney@gmail.com	*1. Dr. Rajendran Prabakaran, International Research Professor, School of Mechanical Engineering, Yeungnam University, South Korea.*	*1. Dr P. Sundaram, SRMIST*
2. Dr. Anto Joseph Deeyoko L, Sustainability Expert, Renewable Cogen Globe Energy, Environment & Climate Change Division, SS Renewable Cogen Pvt. Ltd., Navalur, Chennai – 603 103.	*2. Dr. A. Gurubalan, Assistant Professor, IITB, Mumbai*	*2. Dr. Pankaj Kumar, SRMIST*

Course Code	21MEE548J	Course Name	DESIGN OF HEAT EXCHANGERS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire expertise in the basics of heat exchangers.*
CLR-2:	*familiarize with design considerations of heat exchangers.*
CLR-3:	*gain the knowledge to design tubular heat exchangers.*
CLR-4:	*gain the knowledge to design the compact and plate heat exchangers*
CLR-5:	*familiarize with the two-phase flow heat exchangers*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*identify the basic principles of heat exchangers.*	*2*	*2*	-
CO-2:	*identify the various design features of heat exchangers*	*3*	*3*	-
CO-3:	*analyze the design of tubular heat exchangers*	*3*	*3*	-
CO-4:	*analyze the design of compact and plate type heat exchangers*	*2*	*3*	-
CO-5:	*design condensers, evaporators and cooling towers*	*3*	*3*	-

Module-1 - Principles of Heat Exchanger	***12 Hour***
Principles and Introduction to heat exchangers - Classification of heat exchangers, Recuperator and Regenerator - Construction of tubular heat exchangers - Experiment 1 – Experimental studies on the performance of parallel and counter flow heat exchangers - Construction of plate heat exchangers - Construction of extended Surfaces in heat exchangers - Flow arrangements, Selection of heat exchangers - Overall Heat transfer coefficient, Analysis for parallel flow heat exchanger using LMTD method - Analysis of counter flow & cross flow heat exchanger using LMTD method - Effectiveness and NTU method for Heat Exchanger analysis - Experiment 2 - Simulation studies on heat exchangers with varying flow directions using LMTD and NTU method - Experiment 3 - Simulation studies on heat exchangers with varying flow directions using LMTD and NTU method.	
Module-2 - Design Features of Heat Exchangers	***12 Hour***
Heat exchanger design considerations - Material requirement design codes and its requirement - Heat exchanger design methodology - Experiment 4 – Simulation studies on performance of heat exchangers with effects of turbulence - Effect of turbulence, Effect of friction factor, pressure drop in tube side - Effect of Pressure drop in tube bundles - Heat Transfer and pumping power relationship - Effect of fins arrangement ant its geometry on heat transfer - Experiment 5 – Experimental and simulation studies on performance parallel flow and counter flow heat exchangers by varying inlet temperatures - Fouling of Heat exchangers, effect on heat transfer - Problems in pressure drop and fouling in Heat exchangers - Factors affecting performance of HE/PHE/Condensers/Evaporator.	
Module-3 - Thermal Design of Tubular Heat Exchangers	***12 Hour***
Introduction, Design and analysis of inner tube and outer tube - hydraulic design and analysis of inner tube and outer tube - Surface modification of heat exchangers, finned, Annulus and hairpin heat exchangers - Experiment 6 – Experimental studies on the performance analysis of double pipe heat exchangers by varying flow directions for fixed temperature Design of Double Pipe Heat Exchangers parallel flow and counter flow- Design of double pipe Heat Exchangers counter flow-problems - Basic components of shell & tube heat exchangers - Design of shell & tube heat exchangers - Factors affecting in shell & tube heat exchangers, Shell side heat transfer and Pressure drop - Problems on design of shell and tube heat exchangers and its applications - Heat exchanger of TEMA Classifications and codes, thermal-hydraulic performance parameter - Experiment 7 – Experimental studies on the performance analysis of shell and tube heat exchanger by varying mass flow rate.	
Module-4 - Thermal Design of Compact and Plate Heat Exchangers	***12 Hour***

Types – Merits and Demerits - Compact heat exchangers - Factors affecting compact heat exchangers - Plate heat exchangers, Factors affecting Design of plate heat exchangers - Experiment 8 – Experimental studies on performance analysis of plate and gasketed plate heat exchangers - Factors affecting Design of mixing of plates exchangers - Operational characteristics of the plate heat exchanger - Flow arrangements in plate heat exchangers - Heat transfer and pressure drop calculations - Applications of compact and plate heat exchanger - Gasketed plate heat exchangers, constructional features plate, pack and flame - Experiment 9 – Simulation studies on performance analysis of plate and gasketed plate heat exchangers
Module-5 – Two Phase Heat Exchangers ***12 Hour***
Estimation of heat transfer coefficient during phase change process - Fouling factor and Friction factor - Design procedures - Wilson plots - Experiment 10 – Experimental studies on the performance of condenser Designing the different types of condensers Different types of evaporators- Design procedure, Selection procedure - Thermal Stress calculations, Heat pipes - Experiment 11 – Experimental studies on the performance of evaporator - Design of evaporative condensers and heat pipes - Calculation of condenser surface and downflow condenser - Calculation of evaporator surface and multiple evaporator - Experiment 12 – Simulation studies on performance analysis of condenser, evaporator and heat pipes..

Learning Resources	1. *SadikKakac and Hongtan Liu, "Heat Exchangers Selection, Rating and Thermal Design", CRC Press,2002* 2. *Kern D.Q, "Process Heat Transfer", Tata McGraw Hill , 1997, Reprint 2008* 3. *Ramesh K. Shah, "Fundamentals of Heat Exchanger Design", John Wiley & Sons,2003* 4. *Arthur. P Frass, "Heat Exchanger Design", John Wiley & Sons, 1988.* 5. *Taborek.T, Hewitt.G.F and Afgan.N, "Heat Exchangers, Theory and Practice", McGraw-Hill Book Co.2018*	6. *Kuppan T, "Heat Exchanger design handbook", Marcel Dekker INC, 2000* 7. *Lieke Wang, Bengt Sundén, Raj M. Manglik., Plate Heat Exchangers: Design, Applications and Performance, WIT Press, 2007.* 8. *Standards of Tubular Exchanger Manufacturers Association (TEMA), 9th Edition, 2007.* 9. *Wolverine Heat Transfer Data book – III by Wolverine Tube Inc.,*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	-	30%	30%	-
Level 2	Understand	30%	-	-	30%	30%	-
Level 3	Apply	20%	-	-	20%	20%	-
Level 4	Analyze	20%	-	-	20%	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Lovelyn Theresa, Head – Projects, Energy, Environment & Climate Change (EECC) Division, S S Renewable Cogen Pvt. Ltd., Navalur, Chennai*	1. *Dr. S. Suresh, Professor, Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli - 620 015.*	1. *Dr. C. Selvam, SRMIST.*
2. *Dr. N Saravanan, Principal Engineer, Smart Implements & Machinery and Sustainability, Mahindra*	2. *Dr. Raju Abraham Scientist NIOT, Chennai*	

Course Code	21MEE548T	Course Name	CONVECTION AND TWO-PHASE FLOW	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize with convection heat transfer.*
CLR-2:	*be familiar with the free-convective heat transfer coefficient for different orientation and shapes*
CLR-3:	*acquire the knowledge about forced convection.*
CLR-4:	*acquire the knowledge of two-phase flow behavior*
CLR-5:	*calculate the pressured drop-in two-phase flow*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*discuss the concept of convective heat transfer*	3	-	-
CO-2:	*discuss the various flow and geometry concepts of free convection*	3	2	-
CO-3:	*solve the forced convection problems using various correlations*	3	2	-
CO-4:	*analyze the pressure drop and heat transfer problems for two-phase flow.*	3	2	-
CO-5:	*analyze the various two-phase flow systems*	3	2	-

Module-1 - Convective Heat Transfer	***9 Hour***
Introduction to convective heat transfer and relevant transport phenomena, Free and Forced convection on flow over a flat plate, Internal flow: Fully developed velocity and temperature profiles, Hydrodynamic and thermal entry length in circular tubes, Flow over bodies with boundary layer separation, Conservation principles, Differential equations of the boundary layer, Momentum, Energy, and Mass diffusion equations, Simplified equations for the velocity boundary layer and thermal boundary layer, Integral equation of boundary layer, Equations for turbulent boundary layer.	
Module-2 - Free Convection	***9 Hour***
Introduction to free convection & its applications, Parameters applicable in free convection, Integral equations for momentum and energy analysis on a flat plate, Free-convective heat transfer coefficient for a vertical plane surface, Empirical Correlations for Free Convection (Vertical, Horizontal), Empirical Correlations for Free Convection (Inclined Cylinder), Empirical Correlations for Free Convection (Spheres, Enclosed Spaces), Transition and turbulence in free convection, Mixed convection (Internal and External flows).	
Module-3 - Forced Convection	***9 Hour***
Need for Forced convection, The analogy between momentum and heat transfer, Circular tubes with thermal boundary conditions, Moderate Prandtl Numbers, Eddy diffusivity near the center line of a pipe, fully developed profiles with constant surface temperature, Fully turbulent flow between parallel planes, flow instability, Effect of axial variation of surface temperature and heat flux, Influence of surface roughness, The Moody Chart.	
Module-4 - Behavior of Two-Phase Flow	***9 Hour***
Introduction to two-phase flows, Flow Patterns (bubbly, slug, annular, mist, stratified), Flow pattern Maps, volumetric concentration, void fraction, volumetric flux, Relative velocity, drift velocity in various flow regimes, Development of Homogeneous nucleation (One-dimensional steady homogeneous equilibrium flow, homogeneous friction factor), Separated Flow and Drift Flux, Two-phase flow instabilities, Pressure Drop-in Two-Phase Flow, Lockhart-Martinelli correlation, Parameter X and its evaluation.	
Module-5 – Two Phase Flow Systems	***9 Hour***

Introduction to Two-phase Flow Systems, Active and Passive systems, Design of conventional heat pipes, Micro heat pipes, Pulsating heat pipes, Electronics thermal management, Space thermal management, Classification of Two-phase heat exchangers, Design of Condensers, Design of evaporators

Learning Resources	1. *Bejan, Adrian. Convection heat transfer. John wiley & sons, 2013.* 2. *Martynenko, O.G. and Khramtsov, P.P., 2005. Free-convective heat transfer: with many photographs of flows and heat exchange. Springer Science & Business Media.* 3. *Kays, W.M., Crawford, M.E. and Weigand, B., 1980. Convective heat and mass transfer (Vol. 4). New York: McGraw-Hill.* 4. *Schlichting, H. and Gersten, K., 2016. Boundary-layer theory. Springer.*	4. *Shah, M.M., 2021. Two-Phase Heat Transfer. John Wiley & Sons.* 5. *Chisholm D, Two-phase flow in Pipelines and Heat Exchangers, Longman Inc. New York, 1987* 6. *Tong, Long Sun. Boiling heat transfer and two-phase flow. Routledge, 2018.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	20%	-	30%	-	30%	-
Level 5	Evaluate	10%	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Shaji Sidney, Research and Development, Tan90 Thermal Solution Private Limited, Chennai, India, shajisidney@gmail.com*	1. *Dr. Rajendran Prabakaran, International Research Professor, School of Mechanical Engineering, Yeungnam University, South Korea. prabakaran@yu.ac.kr ; praba.auto@gmail.com*	*1. Dr. P. Chandrasekaran, SRMIST*
2. *Dr. Anto Joseph Deeyoko L, Sustainability Expert, Renewable Cogen Globe Energy, Environment & Climate Change (RCG - EECC) Division, SS Renewable Cogen Pvt. Ltd., Navalur, Chennai.*	2. *Dr. Santosh Ravichandran, Research Associate, Desalination and Separations Group, Los Alamos National Laboratory, Los Alamos, New Mexico, USA 87545. Email ID: santosh@lanl.gov*	*2. Dr. P. Ganesh Kumar, SRMIST*

Course Code	21MEE549T	Course Name	CFD OF TURBOMACHINERY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe turbomachines components and working principle*
CLR-2:	*apply the numerical methods*
CLR-3:	*solve fundamental flow problems in turbomachines*
CLR-4:	*solve the incompressible fluid flow problems in turbomachines*
CLR-5:	*solve the compressible fluid flow problems in turbomachines*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*describe turbomachines components and operations*	3	-	-
CO-2:	*apply the numerical methods*	3	-	-
CO-3:	*solve fundamental flow problems in turbomachines*	3	3	-
CO-4:	*solve the incompressible fluid flow problems in turbomachines*	3	3	-
CO-5:	*solve the compressible fluid flow problems in turbomachines*	3	3	-

Module-1 - Turbomachines	***9 Hour***
Introduction to Turbomachines, Classification of Turbomachines-Turbine/compressor work, Euler's Equation of Energy Transfer, Vane congruent flow, Meridional view and cascade view, Velocity triangles, Concept of specific speed-Axial, Radial and Mixed Flow Machines, Axial turbine stages-Stage velocity triangles-Blade loadings-Case study on performance estimation of Francis turbine, Work, efficiency, flow coefficient of impulse turbine, Single stage and reaction turbines, Degree of reaction-50% reaction turbine	
Module-2 - Numerical Methods	***9 Hour***
Introduction of computational fluid dynamics, Governing equations-Continuity equation-Momentum equation-Energy equation, Grid Generation, Types of grid O, H, C., Discretization of thermally developing flow inside a circular pipe, Structured mesh generation, Unstructured mesh generation-Algebraic methods, Dynamics meshing-Boundary Layer Resolution-Mesh Quality, Modelling of flow past cylinder, Single and multiple rotating frame, Sliding mesh-Periodic meshing-Introduction to Finite Element method.	
Module-3 - Simple Fluid Flow Problems	***9 Hour***
One Dimensional wave equation, one -dimensional steady state heat conduction convection equation, Finite volume formulations for diffusion equation, Finite volume formulations for diffusion equation, Flat plate-boundary layer-Flat plate-boundary layer-exercise, Rotor / stator simulation-Poiseuille flow-Couette Flow-Inlet whirl-Blade shape and number, Blade angle-Blade spacing, modelling of impeller-Turbulent Flow in pipe-Flow in bend pipe, Converging pipe-Diverging pipe	
Module-4 - In-Compressible Flow	***9 Hour***
Pelton turbine, Design aspect of Pelton turbine, Operation of Pelton turbine-Pelton turbine-(Simulation)-Francis turbine-Design aspect of Francis turbine-Impulse turbine-case study, Operation of Francis turbine-Francis turbine-(Simulation)-Kaplan turbine-Operation of Kaplan turbine-Axial flow Bulb type turbine-Axial flow Bulb type turbine(simulation), Axial flow tube type turbine-Axial flow tube type turbine(operation),Axial flow tube type turbine(simulation),Impeller and guide vanes.	
Module-5 – Compressible Flow	***9 Hour***

Concept of Mach number, supersonic flow through converging-diverging nozzle: Governing equations-supersonic flow through converging diverging nozzle, Centrifugal fan-Operation of centrifugal fan-Centrifugal fan (Simulation), Centrifugal fan(case study),Centrifugal compressor-Inducer, Diffuser-Impeller-Discharge duct, Slip in centrifugal impeller, Compressor performance-Centrifugal compressor(simulation),Gas turbine- Turbine(blade),Cooling of turbine blade, Blade fixtures

Learning Resources	1. *Anderson J.D., "Computational Fluid dynamics", McGraw Hill Int., New York, 2010.* 2. *Versteeg H.K., and Malalasekera W., An introduction to computational fluid dynamics, "The finite volume method", Longman, 2007.* 3. *Muralidhar.K, and Sundararajan.T, "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, Second Edition, 2014.*	4. *Suhas.V. Patankar, "Numerical Heat Transfer and Fluid Flow", Hemisphere Publishing Corporation, 2009.* 5. Gopalakrishnan G, Prithvi Raj D, "A treatise on Turbomachines", Scitec Publications, Chennai, 2002. 6. *Computational Fluid Dynamics and Heat Transfer, Pradip Majumdar , CRC Press, 2022*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Parag Deshpande, senior scientist, NAL*	1. *Dr Aviansh Kumar IITDM Kancheepuram*	1. *Dr Pankaj Kumar, SRMIST*
2. *Niloy Ghosh, Director DSN AEROSPACE CONSULTANTS PVT. LTD.*	2. *Dr Vihnu M Teja IIT ISM Dhanbad*	2. *Dr. Santosh Kumar Singh, SRMIST*

ACADEMIC CURRICULA

Thermal Engineering
Specialization: Gas Dynamics/ Renewable Energy

Professional Elective Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21MEE549J	Course Name	COMPUTATIONAL FLUID DYNAMICS FOR ENERGY SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	*acquire knowledge on basic of convection and diffusion problems*
CLR-2:	*acquire knowledge on numerical methods*
CLR-3:	*acquire knowledge on finite volume method*
CLR-4:	*examine the performance of solar energy systems*
CLR-5:	*examine the performance of wind energy systems*

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	*derive governing equations to a fluid system and classify governing equations mathematically*	2	2	-
CO-2:	*implement different discretization techniques to solve simple PDEs,*	3	3	-
CO-3:	*understanding the principle of Grid generation*	3	3	-
CO-4:	*analyze and evaluate the performance of solar energy systems*	3	3	-
CO-5:	*analyze and evaluate the performance of wind energy systems*	3	3	-

Module-1 - Governing Equations	***12 Hour***
Introduction, Conservation and Non conservation form of governing equation-Introduction, Conservation and Non conservation form of governing equation-Evaluation of Finite difference method – tutorials and Case study -Different types of boundary conditions and classification of Partial differential equations-Mathematical behavior of Partial differential equations, Well posed and ill posed problems-Evaluation of Partial differential equations –elliptic, parabolic, hyperbolic-Case study- Formulation and Solution of conduction diffusion equation by the explicit methods - Solution of conduction diffusion equation by the Crank Nicholson and implicit methods - CFD analysis on Venturi -Case study	
Module-2 -Finite Volume Method for Numerical Problems	***12 Hour***
Formulation and Discretization of two dimensional steady state conduction diffusion problem - Discretization of one dimensional steadystate convection diffusion problem - Evaluation of Discretization of two dimensional steady state convection diffusion problems - Properties of discretization scheme, Upwind scheme, hybrid scheme, Quick scheme - CFD analysis on conjugate heat transfer in a solar still - Melting and Solidification -1D phase change - Design. Modeling and Simulation of simple PCM storage system - CFD analysis on PCM storage system - Case study	
Module-3 – Grid Generation	***12 Hour***
Classification of grids - Structured Mesh Generation -Techniques - Case study on Structured Mesh Generation - Mapping layouts-Basic grid configurations - C-type, H-type, O-type grid generation - Case study on mapping layouts - Unstructured Mesh generation -Mesh generation algorithms - Adaptive mesh generations - Case study on Unstructured mesh generation	
Module-4 - Simulation of Solar Energy Systems	***12 Hour***

Classification of Solar collector, Design, procedure and calculation of solar water heating and cooling systems - Mathematical modeling of Flat plate collector water heating system - Simulation of solar Flat plate collector water heating system - Design, procedure and calculation of solar air heater - Mathematical modeling and Performance analysis of air heating system - Mathematical modeling and Performance analysis of air heating system - CFD analysis on solar heating system - Design of photo voltaic Module and its components - Performance analysis of photovoltaic system - Simulation of PV system -Case study
Module-5 –Simulation of Wind Energy Systems **12 Hour**
Wind turbine Energy basics, Blade element and combined blade element theory - Rotor characteristic - Case study on simulation of turbine blades - Design and modeling of wind turbines - Simulation of Turbine losses - CFD analysis of wind turbine losses - Flow modeling of wind turbine using MATlab/SIMULink - Methodology for simulation - Case study on Wind turbine simulation using Mat Lab / SIMULink

Learning Resources	1. *Anderson J.D., "Computational Fluid dynamics", McGraw Hill Int., New York, 2010.* 2. *Versteeg H.K., and Malalasekera W., An introduction to computational fluid dynamics, "The finite volume method", Longman, 2007.* 3. *Suhas.V. Patankar, "Numerical Heat Transfer and Fluid Flow", Hemisphere Publishing Corporation, 2009.* 4. *Muralidhar.K, and Sundararajan.T, "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, Second Edition, 2008.*	5. *.Ghoshdasdidar.P.S, "Computer simulation of fluid flow and heat transfer", Tata McGraw Hill Publishing Company Ltd., 1998.* 6. *Solar Energy-Principles of thermal energy collection & storage, S.P. Sukhatme, Tata McGraw Hill Publishers, 1999* 7. *Solar Energy- Fundamentals, design, modeling & applications, G.N. Tiwari, Narosa Pub., 2005* 8. *Wind Energy Explained – Theory, Design and Application by J. F. Manwell, J. G. McGowan and A. L. Rogers, John Wiley & Sons, Ltd., 2002.*

Learning Assessment							
	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Dr. N Saravanan, Principal Engineer, Smart Implements & Machinery and Sustainability, Mahindra	*Dr. Raju Abraham Scientist NIOT, Chennai*	1. *Dr. P.Sudhakar, SRMIST* 2. *Dr.Siva krishna Reddy, SRMIST*

Course Code	21MEE550J	Course Name	SOLAR ENERGY TECHNOLOGY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1 :	*familiarize with solar radiation and solar thermal collectors*
CLR-2 :	*analyze the performance of solar flat plate collectors*
CLR-3 :	*analyze the performance of concentrated solar thermal collectors*
CLR-4 :	*be familiar with various semiconductor physics and PV technologies*
CLR-5 :	*analyze the design, operation, and performance of solar PV modules*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CLO-1 :	*comprehend the design aspects of solar thermal collectors*	3	-	-
CLO-2 :	*examine the performances of solar flat plate collectors*	3	2	-
CLO-3 :	*examine the performance of concentrating solar collectors*	3	2	-
CLO-4 :	*assess the semiconductor physics and solar cell operation*	2	-	-
CLO-5 :	*analyze the various PV technologies and balance of components*	3	2	-

Module-1 - Basics of Solar Collectors	***12 Hour***
Solar radiation, Fundamentals of solar collectors, Classifications solar collectors, Evacuated type collectors, Flat plate air heaters, Box type solar cookers, Construction details of solar collectors, Design and structures of collectors for heating liquids, Design and structures of collectors for air heating, Practice on fundamentals of Solar Fluidic Systems, Design aspects of Various Solar Collectors – Case study.	
Module-2 - Flat Plate Solar Collectors	***12 Hour***
Flat Plate collectors, Optimal collector tilt and orientation, Thermal performance analysis, Energy balance on solar air heater performance, Useful energy gain, Heat losses and Energy efficiency, Use of selective coatings to enhance the collector efficiency, Flat Plate collectors for low and medium-temperature applications, Flat Plate collectors for medium-temperature applications, Flat plate solar collectors with thermal energy storage, Practice on Solar Flat Plate collectors - thermosyphon and forced modes.	
Module-3 - Concentrating Solar Collectors	***12 Hour***
Concentrating collectors, Various types - Line and point-focusing solar collectors, Parabolic trough solar collectors, Parabolic dish collectors, Heliostat field with a central receiver, Sun tracking mechanisms, Types, procedures and challenges in two-axis tracking Systems, Fresnel lens-based solar collectors, Energy storage for concentrating solar collectors, Practice on parabolic trough solar collector, Practice on parabolic dish solar collector.	
Module-4 - Physics of Solar Cells	***12 Hour***
Cell design-Collection probability and junction depth, Doping of substrate, Back surface fields, Top layer limitations-High doping effects, saturation current density, Top contact design, Optical design- texturing and anti-reflective coating, The production process of single-crystalline silicon cells, multi-crystalline silicon cells, I-V Characteristics of Solar Cell, MPPT, Characteristic resistance, Efficiency limits- Short circuit current, Open circuit voltage, Effect of Temperature, Solar cells in series and parallel, shading-bypass diode, half-cut solar cells, Influence of shunt and series resistance, Maximum power point tracking, I-V and P-V characteristics of Solar PV module - Practice, Case study on efficiency improvement techniques of solar cells.	
Module-5 – Design of PV Systems	***12 Hour***

Design of Solar water pumping system, Solar street light-design, Solar lantern, Solar cars, Solar charging stations, Solar aircraft, Solar PV for satellites, Solar PV-Thermal collectors, Environmental impacts of solar PV systems, Socio-economic impacts of Solar PV systems, Cost analysis of standalone and grid-tied PV power system, Thermal imaging of solar PV module - Practice, Case study on Solar PV power systems.

Learning Resources	*1. Soteris A.Kalogiru, "Solar Energy Engineering: Processes and systems", 1st edition, Academic press, 2009.* *2. Sukhatme .K, Suhas P.Sukhatme., "Solar energy: Principles of thermal collection and storage", Tata McGraw Hill publishing Co. Ltd, 8th edition, 2008.* *3. Duffie .J. A & Beckman .W.A, "Solar Engineering of Thermal Processes", 3rd edition, John Wiley & Sons, Inc., 2006.* *4. Garg .H.P,Prakash .J, "Solar energy fundamentals and applications", Tata McGraw Hill publishing Co. Ltd, 2006.*	*5. Yogi D. Goswami, Frank Kreith, Jan F.Kreider., "Principle of solar engineering", 2nd edition, Taylor and Francis, 2nd edition, 2003.* *6. Green MA. Solar cells: operating principles, technology, and system applications. Englewood Cliffs, NJ, Prentice-Hall, Inc., 2009.* *7. Solanki, Chetan Singh. Solar photovoltaics: fundamentals, technologies and applications. PHI Learning Pvt. Ltd., 2015.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	30%	-	-	30%	30%	-
Level 2	*Understand*	30%	-	-	30%	30%	-
Level 3	*Apply*	20%	-	-	20%	20%	-
Level 4	*Analyze*	20%	-	-	20%	20%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Soumitra Mukhopadhyay, SMS India Pvt. Ltd, Kolkatta	*1. Dr. Ravita Lamba, MNIT Jaipur*	*1. Dr. R. Senthil, SRM IST*
2. Mr. M. Periyasamy, NLC India, Neyveli	2. Dr. G. Kumaresan, Anna University Chennai	*2. Dr. V. Thirunavukarasu, SRM IST*

Course Code	21MEE550T	Course Name	COMBUSTION TECHNOLOGY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the fundamental principles and concepts of chemical reactions in the context of combustion technology*
CLR-2:	*develop a comprehensive understanding of laminar premixed and diffusion flames*
CLR-3:	*explore the complexities and challenges associated with turbulent premixed and diffusion flames*
CLR-4:	*familiarize with the principles and applications of spray combustion*
CLR-5:	*introduce combustion modeling techniques*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand the basic chemistry in combustion systems*	1	-	-
CO-2:	*analyze the characteristics, behavior, and key parameters of laminar premixed flames of SI engine*	1	-	-
CO-3:	*analyze the complexities and challenges associated with diffusion flames of CI engine*	1	-	-
CO-4:	*apply knowledge of spray combustion principles to spray combustion systems*	2	-	-
CO-5:	*evaluate combustion modeling techniques*	3	1	-

Module-1 - Combustion Chemistry	***9 Hour***
Fuels and combustion and Chemical kinetics, Air/ Fuel ratio calculations and actual combustion process, Flammability limits, Flame Temperature, Burning Velocity of a Premixed Flame, Laminar Flame Stabilization, Enthalpy of formation and combustion, First law analysis of reacting system, Adiabatic flame temperature, Second law analysis of reacting system, Entropy change of reacting systems.	
Module-2 - Premixed Flames	***9 Hour***
Theory and Kinetics of Laminar Premixed Flames, Background to Flame Propagation, Kinetic Model of Premixed Flames (burning rate calculation), Computational Method, Transport Parameters, Factors influencing flame velocity and thickness, Flame speed correlations (quenching, flammability and ignition), Factors influencing flame velocity and thickness (Temperature, pressure, Equivalence ratio, fuel type), Flame stabilization, Nonreacting constant density laminar jet, counter flow flames	
Module-3 - Diffusion Flames	***9 Hour***
Characteristics of Diffusion Flames, Diffusion Flame Length, Opposed Diffusion Flames, Turbulent Burning, Interaction Between Turbulence and Chemical Kinetics, The Influence of Turbulence on the Chemical Reactions, Influence of Non-Streamlined Bodies on flame stabilization, Stability of Diffusion Flame, Effect of the Stabilizer Geometry, Stabilization of Free Diffusion Flames, Laminar Flamelet Model, Structure and Heat Release Rate, Turbulent Burning Velocity, Burning Velocity in Closed Systems, Turbulent Free Diffusion Flames, Structure and Height of Diffusion Flames, Effect of Buoyancy, Effect of Relative Angle Between Fuel and Air Jets, Effect of Air Swirl	
Module-4 - Spray combustion	***9 Hour***
Overview, Diesel engine, Gas turbine engines, Liquid rocket engines, Spray statistics, Simple model of Droplet Evaporation and Burning Rate, Gas phase analysis, Droplet lifetime, Species and energy conversion, Simplified conservation equations, Deflagrations in Diffusion combustion, Spray penetration and cloud combustion.	
Module-5 – Combustion Modelling	***9 Hour***
Classification of models, Governing equation for open thermodynamic system – Conservation of Mass and Energy, Intake and Exhaust Flow Model – Quasi steady flow model, Filling and Emptying methods – Gas Dynamic models, Direct Injection Engine Model, Multicylinder and Complex Engine System Models, Fluid Mechanics Based Multidimensional Models – Basic Approach and Governing Equations, Turbulence model, Numerical Methodology, Flow Field Prediction	

Learning Resources		
Learning Resources	1. *Heywood, John B. Internal combustion engine fundamentals. McGraw-Hill Education, 2018.* 2. *Cengel, Yunus A., Michael A. Boles, and Mehmet Kanoğlu. Thermodynamics: an engineering approach. Vol. 5. New York: McGraw-hill, 2011.* 3. *Williams, F. A. "Combustion theory: the fundamental theory of chemically reacting flow systems. benjamin/cummings pub. co." (1985).*	4. *Turns, Stephen R. Introduction to combustion. Vol. 287. New York, NY, USA: McGraw-Hill Companies, 1996.* 5. *Gary.L.Borman, Combustion Engineering-McGraw Hill international Edition,1998*

Learning Assessment								
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*10%*	-	*10%*	-	*10%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*20%*	-	*20%*	-	*20%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	*20%*	-	*20%*	-	*20%*	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	**Internal Experts**
1. T K Dhanashekar Reddy, DSR ECO TECH PVT. LTD	*1. Dr. Saleel Ismail, Associate Professor, National Institute of Technology, Calicut*	*1. Dr S. Balaji, SRMIST*
	2. Dr Anand Krishnasamy, Professor, IITM	

Course Code	21MEE551T	Course Name	HYDROGEN AND FUEL CELLS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*Familiarize the basics of fuel cell technology*
CLR-2:	*Familiarize the fundamentals of electrochemistry involved.*
CLR-3:	*Familiarize the various hydrogen storage methods and thermochemical cycles.*
CLR-4:	*Familiarize the operating principle of fuel cells and various applications*
CLR-5:	*Familiarize the feasibility and environmental benefits of green hydrogen.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the basics and applications of hydrogen and fuel cells.*	1	-	-
CO-2:	*describe the electrochemical reactions involved and fuel characterization techniques.*	2	-	-
CO-3:	*compile the various hydrogen production and storage methods.*	1	-	-
CO-4:	*analyze the types of fuel cells and their operating principles.*	3	-	-
CO-5:	*analyze the LCA and the environmental impact of fuel cells.*	1	-	-

Module-1 - Introduction to Hydrogen and Fuel Cells	***9 Hour***
Overview of Hydrogen: Properties and sources, Hydrogen production methods, Fuel Cells: Basic principle Types, and applications. Introduction to electrochemistry. Importance of green hydrogen in the context of sustainable energy. Fuel cell design and performance, Stoichiometric coefficients and utilization percentages of fuels and oxygen. Mass flow rate calculation for fuel and oxygen in single cell and fuel cell stack. Total voltage and current for fuel cells in parallel and serial connection. Over-potential and Polarizations. DMFC operation scheme, general issues-water flooding. Relevance of electrochemistry to hydrogen and fuel cells. Water management, Polarization in PEMFC.	
Module-2 - Fundamentals of Electrochemistry	***9 Hour***
Electrochemical cells: Structure, Components and working principles. Electrochemical kinetics: Redox reactions, Thermodynamics, reaction rates. Electrode processes: Types of electrodes, electrode reactions, Mass transport phenomena: Diffusion, migration, and convective transport. Electrochemical methods. Derivation of Nernst equation, relation of the fuel consumption versus current output.	
Module-3 - Hydrogen Production and Storage	***9 Hour***
Steam Methane Reforming (SMR): Process description, Efficiency, and environmental impacts. Water Electrolysis: Principles, types. Alkaline, polymer electrolyte membrane, Solid oxide electrolysis, and efficiency. Photoelectrochemical Water Splitting, Biomass and Biological Hydrogen Production techniques, Photoelectrochemical Water Splitting: Materials and efficiency considerations. Fermentation, Dark fermentation, Photo fermentation. Hydrogen Storage Methods: Compressed gas, liquid hydrogen. Thermo chemical cycles, transmission, and infrastructure requirements. Hydrogen Storage Methods: Metal hydrides, and chemical storage. Safety and environmental impacts, Economics of transition to hydrogen systems.	
Module-4 - Fuel Cell Technologies	***9 Hour***
Polymer Electrolyte Membrane Fuel Cells (PEMFC): Structure, working principles and applications. Solid Oxide Fuel Cells (SOFC): Structure, working principles, and applications. Alkaline Fuel Cells (AFC): Structure, working principles, and applications. Direct Methanol Fuel Cells (DMFC): Structure, working principles, and applications. Molten Carbonate Fuel Cells (MCFC) and Phosphoric Acid Fuel Cells (PAFC), Fuel cell usage for domestic power systems, Large scale power generation- Automobile, space applications, Future trends of fuel cells, Economic and environmental analysis on usage of fuel cell, Comparison of battery vs fuel cell.	
Module-5 – Green Hydrogen and Sustainability	***9 Hour***

Green Hydrogen: Definition, production from renewable energy sources. environmental benefits. Life Cycle Assessment (LCA): Evaluating the environmental impact of hydrogen and fuel cell systems. Integration of Hydrogen and Renewable Energy Systems: Power-to-Gas concepts. Power-to-Liquid, and Power-to-Power concepts. Incentives, and market developments for green hydrogen. Future Trends and Research Directions in Hydrogen and Fuel Cells. Electrochemical advancements, materials. Policy and Regulatory Frameworks: International initiatives. Fuel cell characterization.

Learning Resources	1. *Fuel cell Fundamentals, John Wiley and sons, Willey* 2. *Bent Sorensen (Sørensen), Hydrogen and Fuel Cells: Emerging Technologies and Applications, Elsevier, UK (2005)* 3. *Viswanathan, B and M Aulice Scibioh, Fuel Cells – Principles and Applications, Universities Press*	4. *Rebecca L. and Busby, Hydrogen and Fuel Cells: A Comprehensive Guide, Penn Well Corporation, Oklahoma* 5. *Hart, A. B and G. J. Womack, Fuel Cells: Theory and Application, Prentice Hall, New* 6. *York Ltd., LondonJeremy Rifkin, The Hydrogen Economy, Penguin Group,* 7. *Tomorrow's Energy – Hydrogen Fuel Cells and the Prospects for Cleaner Planet, Peter Hoffman, MIT.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*30%*	-	*30%*	-	*30%*	-
Level 2	*Understand*	*30%*	-	*30%*	-	*30%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*10%*	-	*10%*	-	*10%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Ramya, ARCI*	1. *Dr. Karthikeyan, PSG College of Tech.*	1. *Dr. V.Praveena, SRMIST*
	2. *Dr. P. Elumalai, Pondicherry University*	2. *Dr. S.Balaji, SRMIST*

Course Code	21MEE552J	Course Name	CFD AND ITS APPLICATIONS TO ENGINE PROCESSES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*provide a comprehensive understanding of the fundamentals of internal combustion engines and computational fluid dynamics (CFD)*
CLR-2:	*explore different combustion modeling techniques*
CLR-3:	*examine the practical implementation of CFD in internal combustion engines*
CLR-4:	*introduce the principles of CFD applied to gas turbines*
CLR-5:	*explore the latest advancements in CFD techniques and their applications to internal combustion engines*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*demonstrate the basic principles of internal combustion engines and CFD*	2	-	-
CO-2:	*apply combustion modeling techniques*	2	-	-
CO-3:	*utilize CFD tools to simulate and optimize IC Engine characteristic*	2	-	-
CO-4:	*analyze and optimize the performance of gas turbines*	3	-	-
CO-5:	*apply CFD tool to enhance the analysis and optimization of internal combustion engines*	3	2	-

Module-1 - Basics of IC Engines and CFD	***12 Hour***
Overview of internal combustion engines, Basic thermodynamics and fluid mechanics principles in engines, Tutorial on CFD Software Familiarization – ANSYS, Engine performance parameters and metrics, Fundamentals of Computational Fluid Dynamics (CFD), Governing equations of fluid flow and heat transfer, Importing geometry and meshing basics, cleaning up and preparing geometry for meshing, Discretization methods: finite difference ; Numerical schemes for solving CFD equations, Introduction to commercial CFD software, Introduction to meshing methods (structured, unstructured, hybrid), Generating 3D grids for engine components (cylinder, valves, piston).	
Module-2 - Combustion Modeling	***12 Hour***
Theory and kinetics of laminar and turbulent premixed and diffusion flames, Factors influencing flame velocity and thickness, Spray modeling and atomization processes, Defining inlet, outlet, wall, and symmetry boundaries, Engine performance parameters and metrics, Fundamentals of Computational Fluid Dynamics (CFD), Combustion modeling: premixed and non-premixed combustion. *Detailed chemistry models for combustion simulations, Selecting appropriate turbulence models, Setting up solver parameters for engine processes, Ignition models: spark ignition and compression ignition, Flame propagation and flame stability models, Knock prediction and modeling, Simulating in-cylinder flow using the Reynolds-Averaged Navier-Stokes (RANS) equations (Studying air-fuel mixing, swirl, and tumble effects).*	
Module-3 - Application of CFD in IC Engines	***12 Hour***
Classification of models, Governing equations for open thermodynamic systems, Simulating heat transfer within engine components, Investigating temperature distribution in the combustion chamber, cylinder walls, and exhaust system, Intake and exhaust flow models, Thermodynamics-based in-cylinder models, Modeling exhaust gas flow and pressure drop, Analyzing backpressure effects on engine performance, Fluid Mechanics-based multi-dimensional models, Fluid Mechanics-based multi-dimensional models, Extracting and visualizing simulation results, creating contour plots, velocity vectors, and streamlines, Interpreting simulation data to gain insights into engine processes.	
Module-4 - Gas Turbines	***12 Hour***
Working principle and components, Brayton cycle analysis, Turbulence characteristics and its impact on gas turbine performance, Performing sensitivity analysis on key parameters (injection timing, valve lift, etc.), Overview of turbulence models (k-ε, k-ω, Reynolds Stress Model), Combustion modeling approaches for gas turbine combustors (Eddy dissipation, flamelet, etc.), Exploring optimization	

techniques to enhance engine performance, Combustion modeling approaches for gas turbine combustors (Eddy dissipation, flamelet, etc.), Heat transfer mechanisms in gas turbine components (turbine blades, combustion chamber, etc.), Heat transfer modeling using CFD in gas turbines.	
Module-5 – Advances in CFD for IC Engines	***12 Hour***
Two-phase flow modeling: droplet evaporation, wall-film modeling, Combustion instabilities and cyclic variability analysis, presentation on research projects involving CFD-based optimization and design, Large eddy simulation (LES) and direct numerical simulation (DNS), Hybrid electric vehicle modeling and powertrain optimization, Exploring advanced turbulence modeling (LES, DNS), Coupling CFD with other simulation tools (e.g., structural analysis), Analysis of real-world IC engine problems using CFD, Engine performance analysis and optimization ; Emissions prediction and reduction strategies, Reviews on Combustion Modelling research articles.	

Learning Resources	1. *"Internal Combustion Engine Fundamentals" by John B. Heywood* 2. *"Computational Fluid Dynamics: Principles and Applications" by Jiri Blazek* 3. *"Introduction to Combustion: Concepts and Applications" by Stephen R. Turns*	4. *"Turbulence Modeling for CFD" by David C. Wilcox* 5. *"Combustion, Fourth Edition" by Irvin Glassman and Richard A. Yetter*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr Balaji Ravichandran, Team Leader, Design and Innovation, Valeo India Private Ltd*	1. *Dr. Saleel Ismail, Associate Professor, National Institute of Technology, Calicut*	1. *Dr S. Balaji, SRMIST*
	2. *Dr T Venugopal, Professor, Vellore Institute of Technology, Chennai*	

Course Code	21MEE552T	Course Name	HYPERSONIC AND HIGH TEMPERATURE GAS DYNAMICS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	**Data Book / Codes/Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1 :	*get familiarity with basics of thermodynamics, gas dynamics and fluid mechanics*
CLR-2 :	*understand the intricate details of hypersonic inviscid flow theory*
CLR-3 :	*know various analytical methods to obtain skin friction and stagnation point heating rate for hypersonic flows*
CLR-4 :	*grasp the concepts of classical and statistical thermodynamics to calculate the thermodynamic properties of high temperature reacting air.*
CLR-5 :	*be familiar with rate equations of vibrational and chemical non-equilibrium, and normal and oblique shock relations for high temperature reacting air.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Program Outcomes (PO)***		
		1	***2***	***3***
CLO-1 :	*analyze the basic concepts of thermodynamics, gas dynamics and fluid mechanics*	3	1	-
CLO-2 :	*apply the inviscid hypersonic flow theory to calculate the surface pressure over flat plate, cones and circular cylinder*	3	2	-
CLO-3 :	*implement the viscous hypersonic flow theory to calculate skin friction and stagnation point heat transfer rate to flat plate, and blunt bodies.*	3	2	-
CLO-4 :	*calculate the thermodynamic properties of high temperature reacting air using the concepts of statistical thermodynamics*	-	2	3
CLO-5 :	*derive rate equations for vibrational and chemical non-equilibrium, implement them in 1 dimensional gas dynamic equations to develop approximate relations for normal and oblique shock relations for high temperature air*	-	2	3

Module-1 - Review of Basics	***9 Hour***
Fluid mechanics: Conservation equations for mass, momentum and energy, Potential flow over a cylinder, Laminar and turbulent boundary layer flow over a flat plate, Thermal boundary layer and Nusselt number correlations, Thermodynamics: Ideal, perfect and reacting gas, entropy, Isentropic relations for perfect gas flows, Gas Dynamics: Normal shock relations, Oblique shock waves, Expansion fans, Bow shock waves, Blunt body flows, Crocco's theorem, Tutorials: Calculation of boundary layer thickness for over a flat plate for laminar and turbulent hypersonic flows, Derivation of relations for isentropic flows and stagnation point conditions, Tutorials on normal and oblique shock relations.	
Module-2 - Inviscid Hypersonic Flow Theory	***9 Hour***
Approximate hypersonic shock and expansion wave relations, Similarity parameter, Newtonian theory, surface pressure calculation, Lift and drag coefficient calculation for flat plate, Modified Newtonian theory: Cp calculation for a circular cylinder, Approximate methods for flow field computation: Governing equations, Mach number independence, Application of hypersonic similarity to flow over cones, Thin shock layer theory and its applications to detached shock waves, Tutorials: Tutorial on surface pressure calculations over a flat plate, 2 D Inviscid compressible computations over circular cylinders with commercial software, Tutorials on application of hypersonic similarity to predict flow over cone	
Module-3 - Viscous Hypersonic Flow Theory	***9 Hour***
Need of viscous solutions: Skin friction drag and aerodynamic heating, Velocity and altitude map for a typical hypersonic flight, Navier-Stokes equations, similarity parameters, boundary conditions, Boundary layer equations for hypersonic flows, Self-similar solutions, Relations for skin friction, Nusselt number and Stanton number, Application to flat plate case, Correlations for stagnation point heating rate calculation for blunt bodies and sample calculations, Effect of entropy layer on heating rate, short discussion on shock wave/boundary layer interactions. Tutorials on thin shock layer theory, Tutorials on Heating rate calculations for flat plate, Tutorials on calculation of stagnation point heating rate for FIRE II flight data	
Module-4 - Classical And Statistical Thermodynamics	***9 Hour***
Relations for thermally perfect gas, Entropy generation in a mixture of gases for chemically equilibrium and non-equilibrium conditions, Procedure to calculate mixture composition, equilibrium constant, Heat of reaction, Microscopic description of the gases, Most probable microstate, Boltzmann distribution,Thermodynamic properties as a function of partition function for a single chemical species, Calculation of equilibrium	

constant, Calculation of composition of high temperature air, Thermodynamic properties of equilibrium reacting air, **Tutorial -** *Coding practice for calculation of equilibrium composition, Experimental facilities for high temperature flows: shock tubes, free piston shock tunnels, expansion tubes, Ground testing facilities for hypersonic flows*	
Module-5 – Thermo-Chemical Non-Equilibrium at High Temperatures	**9 Hour**
Derivation of perfect gad equation of state with kinetic theory (Self-study), Collision frequency and mean free path, Distribution functions for speed and mean velocity, Vibrational non-equilibrium, Rate equation for vibrational non-equilibrium, Chemical Non equilibrium and it's rate equation, Two temperature model for high temperature non equilibrium air, Normal and oblique shock relations for Thermo-Chemical equilibrium and Non equilibrium flows, Short discussion on application of Non equilibrium Thermo-Chemistry in the design of planetary probes: Design of Thermal protection system, braking system, control systems and communication blockout., Introduction to radiative heating, Tutorial: Literature review on high temperature flows: Earth and Martian atmosphere, Literature review on flight data, Coding practice for normal shock relations,	

Learning Resources	**1.** *Anderson J.D., "Hypersonic and High Temperature Gas Dynamics", 3rd Edition, AIAA Education Series, March 2019.* **2.** *Vincenti W.G., and Kruger C.H.., "Introduction to Physical Gas Dynamics", 6th Edition, Krieger Publishing Company, Florida, 1986* **3.** *Park, C, "Nonequilibrium Hypersonic Aerothermodynamics", 1st Edition, Wiley-Interscience Publication, 1990*	*4. Hirschel, E.H., "Basics of Aerothermodynamics", 2nd Edition, Springer Publication, 2015* *5. Bertin, J.J., "Hypersonic Aerothermodynamics", 3rd Edition, AIAA Education Series, March 1994.* *6. Bird, G.A., Molecular gas Dynamics and the Direct Simulation of Gas Flows,* Oxford Science Publication, 1994 *7. Ansys Fluent User manual, Version 2021.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*20%*	-	*20%*	-	*20%*	-
Level 4	*Analyze*	*20%*	-	*20%*	-	*20%*	-
Level 5	*Evaluate*	*20%*	-	*20%*	-	*20%*	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. P. Subrahmanyam, Scientist, Intel Corporation, USA	*1. Dr. V. Kulkarni, Professor, IIT Guwahati*	*1. Dr. D. Siva Krishna Reddy, SRMIST*
2. Dr. K.N.Murugan, NAL, Bangalore	*2. Dr. Amjad Ali Pasha, Associate Professor, King Abdullaziz University, Saudi Arabia*	

Course Code	21MEE553T	Course Name	WIND ENERGY SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*identify the engineering variables of wind energy*
CLR-2:	*demonstrate the engineering aspects of wind energy systems*
CLR-3:	*describe the basic design of wind energy conversion systems*
CLR-4:	*explain the operation and performance characteristics of wind energy systems*
CLR-5:	*develop the suitable integration system and relate the effect on environment*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*illustrate the fundamentals of wind energy*	3	2	-
CO-2:	*discover the fundamentals of wind energy conversion systems*	3	-	-
CO-3:	*apply the basic design aspects of wind energy systems*	3	-	-
CO-4:	*interpret the performance of wind energy systems*	3	-	-
CO-5:	*demonstrate the wind energy integration and its environmental impact*	3	-	-

Module-1 - Wind Energy Fundamentals	***9 Hour***
Wind Energy: Global potential. Forces influencing wind, Local Wind systems. Wind Speed modeling – Weibull parameters and estimation. Wind Rose diagram. Favorable factors for wind energy generation. Local meteorological data analysis. Wind energy potential measurement systems. Wind Energy Conversion System (WECS), siting. Site selection, Factors	
Module-2 - WECS Machines	***9 Hour***
Wind Energy Conversion: Wind Turbines, Power in the wind, Power extracted from wind. Types of Horizontal and Vertical axis wind turbines, Aerodynamics of Wind Turbines, Aerodynamic analysis of Horizontal Axis Wind Turbine (HAWT). Aerodynamic analysis of Vertical Axis Wind Turbine (VAWT), Rotor elements, Types of Ground level wind machines, Operational requirements of Ground level wind machines	
Module-3 - Design of WECS system	***9 Hour***
Horizontal Axis Wind Turbine (HAWT) - Blade Element Theory. Wake analysis, HAWT rotor design considerations, selection. 2/3 blades and teetering, coning Power regulation, yaw system. Rotor Design, Design of Vertical Axis Wind Turbines (VAWT), Yaw system and Protection of WECS, Tower types, Methods of construction	
***Module-4 -* Operation and Maintenance**	***9 Hour***
Wind turbine loads, aerodynamic loads in steady operation. wind turbulence, Static and dynamic analysis Fatigue analysis, yawed operation and tower shadow. WECS control system, requirements and strategies. Wind turbine Power, torque and speed characteristics. Interpretation of Wind Turbine characteristics and development strategies, Safety of Wind machines and Towers, Maintenance of WECS – Periodical and Predictive, Maintenance and Environmental Issues of WECS.	
Module-5 – Integration and Environmental impact	***9 Hour***
Annual Energy Output (AEO) of Synchronous and asynchronous generators and loads, Integration of wind energy converters to Grid, electrical networks, and inverters. Testing of WECS. Offshore wind farm development and special considerations, significance. Offshore wind form and Green Hydrogen, wind energy generators & their operational Characteristics, Mitigation of Environmental Impacts, WECS Noise mitigation.	

Learning Resources		
Learning Resources	1. *Freris L.L., Wind Energy Conversion Systems, Prentice Hall 1990.* 2. *Spera D.A., Wind Turbine Technology: Fundamental Concepts Of Wind Turbine Engineering, Asme Press, Ny 1994.* 3. *Johnson, G.L., Wind Energy Systems, Prentice Hall, 1985.*	4. *Joshua Earnest And Tore Wizelius, Wind Power Plants And Project Development, Phi Learning Pvt. Ltd., New Delhi, 2011.* 5. *Erichhau, Wind Turbines- Fundamentals: Technologies, Application, And Economics. Springer -Verlag Berlin -Heidelbeg, 2000.* 6. *Burton Tony, Sharpe David, Jenkins Nick, Bossanyi Ervin, Wind Energy Handbook, John Wiley & Sons; 1st Edition (2001);*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	*Experts from Higher Technical Institutions*	*Internal Experts*
1. Dr. K.N.Murugan, NAL, Bangalore	*1. Dr. Amjad Ali Pasha, Associate Professor, King Abdullaziz University, Saudi Arabia*	*1. Dr. G. Kasiraman, SRMIST*

Course Code	21MEE554T	Course Name	ELEMENTS OF GAS TURBINE PROPULSION	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the ideal gas turbine cycles*
CLR-2:	*examine the gas power cycles of various propulsion systems*
CLR-3:	*acquire knowledge on non-rotating mechanical devices*
CLR-4:	*examine the performance of turbines and compressors*
CLR-5:	*understand the performance of gas turbine combustion system*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyze the ideal gas turbine cycles of air-breathing propulsion devices*	2	1	-
CO-2:	*analyze the practical gas turbine cycles of propulsion devices*	2	2	1
CO-3:	*understand the non-rotating mechanical devices in the gas turbine system*	2	2	1
CO-4:	*evaluate the performance of centrifugal and axial flow compressors.*	2	2	1
CO-5:	*investigate the combustion process in the gas turbine combustion system.*	2	1	-

Module-1 - Gas Turbine System and Cycles	***9 Hour***
Classification of turbomachines, Applications of gas turbines, Operation of gas turbines, Constant volume gas turbine, Constant pressure gas turbine, Thermodynamics of Brayton cycle, Regeneration and intercooling, Reheating and their combinations, Gas turbine v/s I.C engines and steam turbines	
Module-2 *- Gas power cycles for Propulsion*	***9 Hour***
Propulsive devices, Performance criteria, Basics of Gas turbine cycles, Cycle performance of turbojet engine, Cycle performance of turbofan engine, Geared turbofan engine, Performances of turboshaft, working principle of turboprop engine, Thrust augmentation & Reverse thrust	
Module-3 - Inlets, Diffusers and Nozzles	***9 Hour***
Working principle of non-rotating machines, Functioning of subsonic and supersonic inlets, P-V and T-S diagrams for inlets, Performance of diffusers, Normal – shock diffuser, Diffusers with internal contraction, Functions of exhaust nozzles, Area ratio of nozzle, Noise suppression in nozzles	
Module-4 - Compressors and Turbines	***9 Hour***
Classification of turbines and compressors, dynamics of compressor, Operation principles of compressors, Static and total head of compressor, Velocity vector diagrams & degree of reactions, Surging, choking and stalling, Construction and operation of axial flow turbines, Overall turbine performance, Turbine blade cooling	
Module-5 – Combustion Systems	***9 Hour***
Types of combustion chambers, Combustion process, Combustion efficiency, Flame stability, Primary zone mixture strength analysis, Fuel Injection methods, Ignition in the gas turbine, Influence of combustion chamber variables on minimum ignition energy, Combustion Instability	

Learning Resources	1. *Gas Turbine Theory, Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Pearson Prentice Hall, 2017, 7th Edition* 2. *Gas Turbines, Ganesan, V., Tata McGraw Hill, 2017, 3rd Edition* 3. *Gas Turbine Combustion – Alternative Fuels and Emissions, Lefebvre, A.H. and Ballal D. R., CRC Press, 2010*	4. *Turbines, Compressors and Fans, Yahya, S. M, Tata McGraw Hill Education, 2017, 4th Edition* 5. *Aircraft power plants, Thomas W. Wild, McGraw – Hill Education, 2016, 9th edition*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Gireesh Yanamashetti, National Aerospace Laboratory, Bangalore*	1. *Dr. V. Babu, Professor, IIT Madras*	*1. Dr M. Gunasekaran, SRMIST*
2. Dr. G. MuthuSelvan, National Aerospace Laboratory, Bangalore	2. *Dr Ranjith Mohan, IIT Madras*	*2. Dr Siva Krishna Reddy, SRMIST*

Course Code	21MEE555T	Course Name	DESIGN OF TURBOMACHINES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on basic design principles of turbomachine*
CLR-2:	*examine the performance of fans and blowers*
CLR-3:	*investigate the design performance of turbines*
CLR-4:	*examine the design performance of compressors*
CLR-5:	*examine the design aspects of turbomachines*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyze the principal design of turbomachines*	2	-	-
CO-2:	*design and evaluate the performance of fans and blowers*	2	2	1
CO-3:	*design and analyze the performance of turbines*	2	3	1
CO-4:	*examine the design performance analysis of compressors*	2	3	1
CO-5:	*analyze the design aspects of turbomachines*	2	3	2

Module-1 - Introduction to Turbo Machines	***9 Hour***
Classification of Turbomachines, Dimensional analysis, Model and Similitude, Compressible flow machines, Second law of thermodynamics, Brayton cycle for gas turbines, Efficiency and losses, Efficiency of compressors, Energy transfer in turbomachines	
Module-2 - Design of Fans and Blowers	***9 Hour***
Working principles of fans and blowers, Types of fan and blower, Stage and design parameters, Design of impeller blades, Design of volute casing, Design of diffusers, Characteristic curves and selection, Drives, Noise problems in fans and blower	
Module-3 - Design of Compressors	***9 Hour***
Principles of operation, Various components and their functions, Stage velocity triangles, Types - Impellers, diffusers and casing, Design of impellers, Design of casing, Losses and efficiency of Compressor, Low hub-tip ratio, slip factor, Performance characteristics	
Module-4 - Design of Turbines	***9 Hour***
Working principle, Stage velocity triangles, Methods of improving cycle efficiency, Design of turbine blading, performance at varying loads, Blade to gas speed ratio, Performance characteristics, Blade attachment techniques, Critical speeds and balancing of rotors	
Module-5 – Design Aspects of Turbomachines	***9 Hour***
Compressor and turbine operating maps, Design point matching of turbine, Design point matching of nozzle, Variable geometry performance at off design configuration, Variable geometry performance at off design configuration, Single spool Turbo jet component matching, Engine off design analysis, Engine performance testing, Engine performance testing	

Learning Resources	1. *Gas turbine Design, Components and system design integration, Springer publication, Texas A & M University, USA 2018* 2. *Turbomachinery Design and Theory, Marcel Dekker, Inc, New York, 2003* 3. *Gas Turbine Theory, Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Pearson Prentice Hall, 2017, 7th Edition*	4. *Principles of Turbomachinery, Seppo A. Korpela, John Wiley and Sons, 2011, First edition* 5. *Turbines, Compressors and Fans, S. M. Yahya, Tata – McGraw Hill ltd* 6. *Principles of Turbomachines, D. G. Shepherd, The MacMillans Co, 1964*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Gireesh Yanamashetti, National Aerospace Laboratory, Bangalore*	1. *Dr. V. Babu, Professor, IIT Madras*	**1.** *Dr M. Gunasekaran, SRMIST*
2. *Dr. G. MuthuSelvan, National Aerospace Laboratory, Bangalore*	2. *Dr Ranjith Mohan, IIT Madras*	**2.** *Dr Siva Krishna Reddy, SRMIST*

Course Code	21MEE556T	Course Name	FLOW AND THERMAL INSTABILITIES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on instability in flow*
CLR-2:	*examine the serval events in transition*
CLR-3:	*examine the stability of parallel flow*
CLR-4:	*examine the thermal instability*
CLR-5:	*acquire knowledge on instabilities in multiphase systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain fundamental theory behind hydrodynamic stability*	3	-	-
CO-2:	*analyze stability and instability of various flows from both a mathematical and a physical perspective*	3	-	-
CO-3:	*analyze the stability of parallel flow*	3	-	-
CO-4:	*analyze the thermal and centrifugal instability*	3	-	-
CO-5:	*solve the instabilities problems in multiphase systems*	3	-	-

Module-1 - Basics of Instability	***9 Hour***
Review of preliminary concepts in vectors and their operations, Methods for describing fluid motion, material derivative and acceleration, Integral forms of conservation equations, Conservative and non-conservative forms of momentum equation, separation, and control, Mechanics of boundary layer transition, Several events of transition, Examples of transition, Flow in a curved channel, Physical description of the instability	
Module-2 - Transitional and turbulent flows	***9 Hour***
Boundary layer theory, Numerical solution of the thin shear layer equation, Wave interaction: group velocity and energy flux, Issues of space-time scale resolution of flows, Temporal scales in turbulent flows, Computing time-averaged and unsteady flows	
Module-3 - Stability of Parallel Flows	***9 Hour***
Stability of plane parallel flows of an inviscid fluid, General Properties of Rayleigh's stability Problem, Nonlinear perturbations of a parallel flow of an inviscid fluid, Properties of the Orr-Sommerfeld equation and boundary Conditions, Numerical methods of solving Orr-Sommerfeld problem, Rayleigh Ritz method	
Module-4 - Thermal and Centrifugal Instability	***9 Hour***
Rayleigh-Benard thermal convection instability, Boussinesq equations, Rigid and free boundary conditions, Introduction to nonlinear stability, Centrifugal instability: Linear inviscid analysis, Taylor-Couette instability, Seminar on Taylor-Couette instability	
Module-5 – Instabilities in Multiphase Systems	***9 Hour***
Interfacial/surface tension, Stress tensor formulation on arbitrary surfaces, Interfacial boundary conditions, Rayleigh-Taylor instability, Kelvin-Helmholtz instabilities, Rayleigh-Taylor instability, Demonstration of wind waves experimentally, Surface gravity waves, Internal gravity waves, Capillary jet instability	

Learning Resources	1. *Drazin, P.G. and Reid, W.H., Hydrodynamic stability, Cambridge university press (2004* 2. *Holmes, M.H., "Introduction to Perturbation Methods," Springer (2012)*	3. *Charru, F., "Hydrodynamic Instabilities," Cambridge University Press (2011).* 4. *Sengupta, T.K., "Instabilities of flows and transition to turbulence, CRC Press, (2012).*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Parag Deshpande, senior scientist, NAL	*1. Dr Aviansh Kumar IITDM Kancheepuram*	*1. Dr Pankaj Kumar, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr Vihnu M Teja IIT ISM Dhanbad*	*2. Dr. Santosh Kumar Singh, SRMIST*

Course Code	21MEE557T	Course Name	POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize with the fundamentals of power electronics*
CLR-2:	*understand the operation of power electronic converters for solar photovoltaic power systems*
CLR-3:	*familiarize with the operation of power electronic converters for wind energy systems*
CLR-4:	*understand the working of renewable hybrid power plant*
CLR-5:	*get familiar with the design of solar operated electric vehicles*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*discuss the fundamentals of power electronics*	*2*	*1*	*3*
CO-2:	*explain the operation of power electronic converters for solar photovoltaic power systems*	*2*	*1*	*3*
CO-3:	*illustrate the operation of power electronic converters for wind energy systems*	*2*	*1*	*3*
CO-4:	*discuss the working of renewable hybrid power plant*	*2*	*-*	*3*
CO-5:	*examine the design of solar operated electric vehicles*	*2*	*1*	*3*

Module-1 - Introduction to Power Electronics	***9 Hour***
Introduction to power electronics, Review of basic electrical circuits and magnetic concepts, Scope and application of power electronics, Power electronics vs. linear electronics, Power semiconductor switches- Diode, MOSFET, IGBT. Desired Characteristics in Controllable Switches, switching characteristics, Literature review: Decoding the datasheet of the power electronic switch.	
Module-2 - Power electronics for Solar Photovoltaic Systems	***9 Hour***
Working of Solar photovoltaic (PV) cell, Solar photovoltaic panel characteristics, Power electronic converter requirements for photovoltaic power system, Maximum Power Point Tracking (MPPT) of Photovoltaic panels, MPPT techniques and algorithms, Power electronic converters used for solar PV, Standalone photovoltaic power system, Grid connected system and Islanding mode, Battery charging in PV systems. Field Visit: Solar photovoltaic power plant, Case study: Design of solar powered LED street lighting circuit.	
Module-3 - Power Electronics for Wind Energy Systems	***9 Hour***
Wind turbine characteristics, PMSM and DFIG for wind generators, Grid requirement for wind energy, Maximum Power Point Tracking of wind turbines, MPPT techniques and algorithms, Wind turbine control techniques, Power electronic converters for PMSM and DFIG, Micro wind turbines and standalone system, Offshore wind energy systems, Literature review: Offshore wind energy conversion systems.	
Module-4 - Renewable Hybrid Power Plants	***9 Hour***
Need for hybrid energy systems and Duck curve, Range and type of renewable hybrid systems, Wind-PV hybrid systems, Diesel-PV hybrid systems, Microhydel-PV hybrid systems, Biomass-Diesel hybrid systems, Fuel cell system, Power electronic topologies for fuel cell energy systems, PV-fuel cell hybrid systems. Case study: Solar microinverter for bifacial photovoltaic panels, Renewable hybrid power plant for telecom stations.	
Module-5 – Power Electronics for Solar Operated Electric Vehicles	***9 Hour***
Introduction to electric vehicles and their operation, Design of power requirements of electric vehicles Selection of motor and battery for electric vehicle, Electric vehicle battery management systems, Thermal management of battery, Traction motor characteristics, Power electronics for traction motor, Solar operation of electric vehicles. Case study: Calculating the energy requirement for electric vehicle for a drive cycle.	

Learning Resources	1. *Luo FL, Ye H. Advanced DC/AC inverters: applications in renewable energy. CRC Press; 2017.* 2. *R. W. Erickson, D. Maksimovic, Fundamentals of Power Electronics, Kluwer, Academic Publishers, 2nd ed., 2001.*	3. *N. Mohan, T. M. Undeland, and W. P. Robbins, Power Electronics: Converters, Applications, and Design, John Wiley & Sons, 3rd ed., 2007.* 4. *M. H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson Education India, 4th ed., 2017*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Vasudevan. B, Siemens ltd., Bangalore*	1. *Dr. Chandrasekaran S, NIT Hamirpur, Himachal Pradesh*	1. *Dr. S. Manikandan, SRMIST*