DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY(ISM) DHANABD

SYLLABUS OF M.TECH (MECHANICAL ENGINEERING)

SPECIALIZATION: THERMAL ENGINEERING

FIRST SEMESTER					
Course No.	**Course Name**	**L**	**T**	**P**	**CH**
	DEPARTMENTAL CORE				
MEC502	Numerical Methods	3	0	0	9
MEC507	Incompressible and Compressible Flow	3	0	0	9
MEC508	Advanced Heat Transfer	3	0	0	9
MEC509	Advanced Thermodynamics	3	0	0	9
MEC510	Refrigeration and Air-conditioning	3	0	0	9
	Practicals				
MEC511	Thermal Engineering Laboratory –I	0	0	3	3
MEC512	Thermal Engineering Laboratory –II	0	0	2	2
	Total	**15**	**0**	**5**	**50**

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**MEC502**	**Numerical Methods**	3	0	0	9

Course Objectives

The objective of the course is to study the numerical solution of linear and non-linear algebraic equations, solution of differentiation, integrations, PDEs and ODEs.

Learning Outcomes

Upon successful completion of this course, students will:

1. be able to solve actual problems by using different numerical methods.

2. be able to use FDM for discretization of governing equations to find the temperature distribution in the given geometry.

3. be able to understand the different types of PDEs.

4. be able to use the upwinding for solving the flow problems.

5. be able to write the computer programming based on learning of this course.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction to Numerical methods	1	Numerical methods are gradually becoming the substitute of experimental methods
2	Solution of linear algebraic systems: Non-iterative method, Gauss elimination method, LU-factorization method, Matrix inversion method. iterative method, Gauss Seidel iterative method, Jacobi method, ill -conditioning problems, Tridiagonalization, Hoseholder’s method, QR-factorization	8	This unit will help students in understanding the numerical solution methodology for linear equations

3	Solution of non-linear algebraic systems: Solution of equations by iterations, Fixed point iterations, Newton's method, Secant method, Bi-section method	5	Understanding the methods for solution of non-linear equations
4	Numerical differentiation: Methods for first order ODEs, Euler method, Runge-Kutta methods, Methods for higher order and systems of ODEs, Euler method, Runge-Kutta methods, Stiff systems	5	This unit will help students in understanding the applications of Euler's Method, R-K2 and higher order R-K 4 methods
5	Numerical integration: Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule. Numerical double integration	5	Numerical integrations will be very useful for summation and averaging. Also, students will learn about best technique for integration.
6	Introduction to partial differential equations: 1ST Order PDEs, Mathematical classification second order PDEs, Characteristics	2	Understanding the behavior of PDE equations
7	Finite Difference Methods: Different discretization techniques of PDE equations, Backward, forward and central differencing discretization schemes, Euler's explicit, implicit and semiimplicit methods, Truncation, Discretization, Round off errors. Consistency, stability and convergence. Fourier or von-Neumann stability analysis of Finite difference schemes	8	Understanding different types of errors, consistency, stability and convergence during solving the governing equations
8	Applications to model problems: Parabolic equations, heat equations, Elliptic equations, Laplace and Poisson's equations. Dirichlet problems, ADI method, Neumann and Mixed problems, Hyperbolic equation, wave equation, Upwinding differencing scheme of advection terms	5	Students may use different methods for solving the actual heat/fluid flow and wave equations

Text Books:

1. Introductory Methods of Numerical Analysis: S. S. Sastry, 4th Edition, Prentice Hall of India Pvt Ltd.

References:

2. Numerical Solution of Partial Differential Equations: G. D. Smith, Oxford University Press, 1985.

3. Computational Fluid Mechanics and Heat Transfer: D. A. Anderson, J. C. Tannehill and R. H. Pletcher, Hemisphere Publishing Corporation.

4. Computational Fluid Flow and Heat Transfer: K. Muralidhar and T. R. Sundararajan, Narosa Publishing House.

5. Computational Methods in Engineering: S. P. Venkateshan and P Swaminathan, Ane Books Pvt Ltd.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**MEC507**	**Incompressible and Compressible Flow**	3	0	0	9

Course Objectives
1. To broaden the perspectives of fluid dynamics that the students were introduced to in their first level undergraduate course of Fluid Mechanics. 2. To introduce new and advanced topics in details to the students that will increase their curiosity, improve their ability to explain fluid flow through physics supported by mathematical analysis besides enhancing the understanding of theoretical fluid dynamics.
Learning Outcomes
1. Students will be writing or expanding differential equations using indicial notations. This will certainly help them in their journey through research papers during the Masters research. 2. Strong foundation of the viscous, incompressible flow equations and their forms. 3. Understanding of the close coupling between Fluid Mechanics and Thermodynamics.

Modules	Topics	Lecture hours	Learning outcomes
1	Generalized curvilinear coordinates, Introduction to tensors	2	To express a given differential equation in generic form independent of coordinate system. This generic form is also brief in appearance
2	Reynolds Transport Theorem (RTT), derivation of the continuity and momentum equations, the conservation equations in vector and tensor forms, conservation equations in Cartesian, cylindrical polar and spherical polar coordinates	4	Bridging the particle and point approaches of mechanics, express any conservation equation using vector or tensor notations, express the conservation equations in various alternate forms, i.e. conservative, non-conservative, stress-divergence, etc

3	Analytical solutions of Navier-Stokes equations of motion	2	To identify the scant cases of viscous flow where closed form solutions of momentum equations are possible. Simplification of full Navier-Stokes equations under these special cases
4	The concept of boundary layer, Prandtl's boundary layer theory and its limitations, boundary layer equations over a flat plate at zero incidence and similarity solution by Blasius, momentum integral equation, Karman-Pohlhausen method, separation of boundary layer	6	To perform scale analysis and reduce a differential equation to its simplified form, identify similarity variable and perform similarity solution, numerically solve a non-linear ODE, explain fluid forcing based on separation phenomenon
5	Forces on immersed bodies – drag and lift	2	Calculation of global fluid force from distributed fluid forces over a surface, to explain the contributions of surface pressure, body shape and separation points in controlling fluid loading
6	Transition to turbulence, concepts of turbulence modeling, space and time scales of turbulence, space correlation and cross-correlation, Reynolds form of the continuity and momentum equations.	5	To distinguish between the laminar and turbulent flows with further depth and insight, to familiarize with the basic approximate equations employed in analyzing turbulence
7	Compressible Flow, Thermodynamic relations of Perfect gases, Stagnation properties	2	Students will have clear idea of the coupling of compressible fluid flow with the fundamentals of thermodynamics
8	Isentropic flow with variable area duct and Flow with normal shock waves	5	Ability to distinguish between pure one-dimensional and quasi-one dimensional flows. Understanding of the normal shock theory
9	Supersonic wind tunnels, Flow with oblique shock waves, oblique shock relations from normal shock equations, Mach waves	8	Understanding of the oblique shocks as well as thermodynamic relations of oblique shocks
10	Flow in constant area ducts with friction and flow with heat transfer	3	Control volume treatment of one dimensional Rayleigh-line and Fanno line flow

Text Books:

1. F. M. White, Viscous Fluid Flow, McGraw-Hill, New York, 2nd Edition, 2012.

2. Philip J. Pritchard and John W. Mitchell, Introduction to Fluid Mechanics, Fox and McDonald's, John Wiley & Sons, 9th Edition, 2016**.**

References:

3. R. L. Panton, Incompressible Flow, John Wiley & Sons, 4th Edition, 2013.

4. H. Schlichting, Boundary Layer Theory, Springer, 8th revised Edition, 2001.

5. W. Yuan, Foundation of Fluid Mechanics, PHI, S.I. unit Edition, 1988.

6. V. Babu, Fundamentals of Gas Dynamics, Wiley-Blackwell, Chennai, 2nd Edition, 2015.

7. P. H. Oosthuizen and W. E. Carscallen, Compressible Fluid Flow (Engineering Series), McGraw-Hill Science/Engineering/Math, 1st Edition, 2003.

8. S. M. Yahya, Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, New Age International, 2018.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**MEC508**	**Advanced Heat Transfer**	3	0	0	9

Course Objectives
This course is designed to make the student understand the basic principles of heat and mass transfer, and to develop methodologies for solving wide varieties of practical engineering problems.
Learning Outcomes
Upon successful completion of this course, students will: 1. have a broad understanding of advanced topic of heat transfer. 2. have analytical and mathematical tools to handle complex heat transfer problem. 3. be able to provide some basic solution to real life heat transfer problems.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction to Conduction, convection and radiation heat transfer, 1-D Steady State Heat Conduction, Heat conduction in non-isotropic materials, Fins with variable cross-section, Moving fins. Conduction shape factor, Multi-dimensional steady state heat conduction, Graphical Method: (The Schmidt Plot)	5	Students will review the basic heat transfer. They will learn about steady state conduction and its application
2	Improved lumped models, Duhamel's superposition integral. Transient heat flow in a semi-infinite solid: The similarity method, The integral method	5	Transient heat conduction and its analysis will be learned
3	Heat equation for moving boundary problems, Stefan's solution. Moving Heat Sources	4	Specific topics discussing about moving boundary problem will be analyzed

4	Momentum and Energy Integral Equations, Thermal ad hydrodynamic boundary layer thickness, Heat transfer in a circular pipe in laminar flow when constant heat flux and constant wall temperature to the wall of the pipe, convection correlations for turbulent flow in tubes, Flow over cylinders and spheres, Flow across tube bundles/banks. Heat transfer from a vertical plate using the Integral method	10	Student will be able to understand convection heat transfer. They will be able to analyze the problem mathematically and relate it to real life example
5	Free convection in enclosed spaces, Mixed convection, High speed flows	5	Students will be able to differentiate between forced and free convection. They will also learn to analyze the mixed convection problems
6	Radiation heat transfer, View factors: Cross string method, unit sphere and inside sphere method, Radiant energy transfer through absorbing, emitting and scattering media, Radiative transfer equation, Enclosure analysis in the presence of an absorbing or emitting gas	6	Students will be able to analyze the radiation heat transfer
7	Heat exchangers	4	Students will understand the importance of heat exchanger and its use in process industries

Text Books:

1. F. Incropera and D. J. Dewitt, Fundamentals of heat and mass transfer –Wiley & Sons Inc., 7th Edition, 2011.

Reference Books:

2. K. Muralidhar and J. Banerjee, Conduction and Radiation, 2nd Edition, Narosa, 2010.

3. Latif M. Jiji., Heat Conduction, Springer, 3rd Edition, 2009.

4. A. Bejan, Convective Heat Transfer, J. Wiley & Sons, 3rd Edition, 2004.

5. M. F. Modest, Radiative Heat Transfer, Academic Press, 3rd Edition, 2013.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**MEC509**	**Advanced Thermodynamics**	3	0	0	9

Course Objectives

To make the students conversant with the fundamentals of thermodynamics and to apply the principles to various thermal systems.

Novelty: Advanced topics like Exergy analysis of reactive systems and introduction to irreversible thermodynamics are introduced.

Learning Outcomes

Upon successful completion of this course, students will:

1. have a broad understanding of basic concepts of thermodynamics.

2. have a thorough understanding of entropy and be able to estimate rate of entropy generation in different thermal systems undergoing actual processes.

3. be able to apply exergy analysis to both reactive and non reactive systems undergoing thermodynamic cycles or processes and estimate the associated reversible work and irreversibility.

4. be able to apply the thermodynamic property relations to calculate various thermodynamic properties using the measured properties.

5. understand the theory and concept of thermodynamics for non-equilibrium systems.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction: Review of basic thermodynamics, First law for a closed system, Caratheodory's approach, Uncoupled and coupled systems, General conservation of energy principle for control volume, Transient flow analysis, Charging and discharging of rigid vessels, Transient analysis with boundary work	5	Understanding of basic concepts and applying the conservation of energy principle to both control mass and control volumes, both for steady and transient conditions

2	Second Law of Thermodynamics and Entropy: Physical meaning of Second law, Statement of Second law, External and internal irreversibility, Introduction to entropy, its statistical interpretation, Caratheodory's axiom II, Entropy balance equation for closed system and control volume. Entropy measurement and its evaluation, Mechanism of entropy generation: Heat transfer across finite temperature difference, Flow with friction, Mixing. Entropy generation number	5	This unit will help the students to understand the limitations of first law and how 2nd law will be useful in overcoming the same. The student will be able to apply the entropy balance to both closed and open systems with view to estimating the related entropy generation in various engineering devices
3	Exergy: Introduction, Availability and exergy of systems Availability or exergetic efficiency, Generalized exergy analysis	8	This unit will make the student understand the concept of exergy and to estimate the available and unavailable part of any low grade energy source
4	Thermodynamic Property Relations: Introduction, The Maxwell's relations, The Gibbs and Helmholtz relations, The Clapeyron Equation, General relations involving enthalpy, internal energy and entropy, Co-efficient of volumetric expansion, Isothermal compressibility. Joule Thomson coefficient, Jacobeans' in Thermodynamics	8	This chapter will familiarize the students with thermodynamic property relations, using which the student will be able to estimate different calculated thermodynamic properties from the measured ones
5	Non-Reactive Gas Mixtures: Introduction, basic definitions for gas mixtures, PVT relationship for mixtures of ideal gases, entropy change due to mixing	4	This will help the students to calculate various thermodynamic properties of homogeneous gas mixtures from the known properties the constituents
6	Reactive Gas Mixtures: Introduction, fuels and combustion, theoretical and actual combustion processes, enthalpy of formation and enthalpy of reaction, adiabatic flame temperature, first and second law analysis of reacting systems, Chemical exergy	5	Upon successful completion of this chapter student will be able to apply 1st and 2nd law to reacting systems and to estimate the heat reaction, adiabatic flame temperature etc

7	Irreversible thermodynamics: Introduction to irreversible thermodynamics, Onsager's reciprocal theorem	4	This chapter will help the student understand the theory and concept of thermodynamics for non-equilibrium systems

Text Books:

1. Kenneth Wark, McGraw-Hill, Advanced thermodynamics for engineers, 3rd Edition, 2013.

References:

2. D. E. Winterbone and Ali Turan, Advanced Thermodynamics for Engineers, 2nd Edition, Elsevier, 2015.

3. Sonntag, Borgnakke and Van Wylen, Fundamentals of Thermodynamics , 7th Edition, John Wiley & Sons, 2009.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**MEC510**	**Refrigeration and Air-conditioning**	3	0	0	9

Course Objectives
To impart knowledge dealing with computation aspects of Refrigeration and Air-conditioning system. This course is essential for design of Refrigeration plant.
Learning Outcomes
Upon successful completion of this course, students will: 1. Illustrate the fundamental principles and applications of refrigeration and air conditioning system. 2. Obtain cooling capacity and coefficient of performance by conducting test on vapor compression refrigeration systems. 3. Present the properties, applications and environmental issues of different refrigerants. 4. Calculate cooling load for air conditioning systems used for various applications. Operate and analyze the refrigeration and air conditioning systems.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction: Definitions brief history and applications, Review of first and second law of thermodynamics, Carnot theorem related to refrigeration	2	Students will know the use of thermal properties in engineering and other applications
2	Air-cycle Refrigeration: Different cycles, advantages and disadvantages, applications in aircrafts	6	An ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political ethical health

3	Vapour Compression Refrigeration: Analysis and performance of basic cycle, cycles with Sub cooling and Superheating, Effects of operating parameters, Multi-pressure and Cascade systems	8	An ability to identify, formulate and solve engineering problems
4	Vapour Absorption Refrigeration: Aqua-ammonia, LiBr-water and three-fluid absorption systems – description and performance analysis	4	Known about the factor affecting the evaporator capacity, condenser capacity with relative the mathematical equation
5	Refrigerants: Classification and nomenclature, Desirable properties, ODP and GWP, Alternative refrigerants	3	The understanding of air properties and relative technical term cooling load in air refrigeration system.
6	Non-Conventional Refrigeration: Principle and operation of Ejector refrigeration system, Thermoelectric refrigerator, Vortex tube or Hilsch tube refrigerator, Pulse Tube refrigerator, Adiabatic demagnetization refrigerator	4	Calculations of cooling load, sensible heat and lateral heat in air conditioning system involve the usage of property equations framed earlier
7	Introduction to Air Conditioning: Psychometric properties and chart, various psychometric processes	4	An ability to design a air-conditioning system
8	Requirements of comfort air-conditioning, Cycles for summer and Winter air-conditioning, bypass and sensible heat factor, fresh air load, ventilation load	4	Air-conditioning system to meet desired needs in different environment condition
9	Estimation of cooling load and heating load and selection of air-conditioning cycles, Different air-conditioning systems	4	The understanding of air properties and relative technical term cooling load in air conditioning system

Text books:

1. C. P. Arora, Refrigeration and air conditioning, Tata McGraw-Hill, 3rd Edition, 2010.

References:

2. R. C. Arora: Refrigeration and Air Conditioning, PHI, 2nd Edition, 2012.

3. Wilbert F. Stoecker and Jerold W. Jones, Refrigeration and air conditioning, McGraw-Hill Inc., US, 2nd Revised Edition, 1982.

4. Roy J. Dossat and Thomas J. Horan, Principles of refrigeration, Pearson, 5th Edition, 2001.

5. Manohar Prasad, Refrigeration and Air Conditioning, New Age International, Revised 2nd Edition, 2009.

6. Anantha Narayana, Refrigeration & Air Conditioning, Tata McGraw-Hill, 4th Edition, 2013.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**MEC511**	**THERMAL ENGINEERING LAB-I**	0	0	3	3

List of Practicals
1. Lift and drag measurements for flow over an airfoil 2. Visualization of flow over an airfoil 3. Experiment on Plate Heat Exchanger 4. Experiment on Cross - Flow Heat Exchanger 5. Experiment on Boiling heat transfer 6. Experiment on condensation heat transfer 7. Heat Transfer coefficient in free convection 8. Heat Transfer coefficient in forced convection 9. Heat Transfer coefficient in mixed convection 10. Temperature distribution in fin

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**MEC512**	**THERMAL ENGINEERING LAB-II**	0	0	2	2

List of Practicals
1. Performance test on gas turbine 2. Performance test on steam turbine 3. Performance test on surface condenser 4. Determination of dryness fraction of steam 5. Experiment on chevron type Heat Exchanger 6. Performance test on 4 cylinder 4 stroke turbocharged diesel engine 7. Computerized Morse test on petrol engine 8. Performance test on shell and tube heat exchanger 9. Experiment on heat pipe 10. Experiment on micro-channel

2^{ND} Semester

Course No.	Course Name	L	T	P	CH
	DEPARTMENTAL ELECTIVES (ANY THREE)				
	Basket 1				
MED538	Gas Dynamics	3	0	0	9
MED539	Fundamentals of Aerodynamics	3	0	0	9
MED540	Fundamentals of Aeroacoustics	3	0	0	9
MED541	Microfluidics	3	0	0	9
MED542	Finite Element Method in Thermal Engineering	3	0	0	9
	Basket 2				
MED543	Solar Energy	3	0	0	9
MED544	Advanced Steam Power Plant	3	0	0	9
MED545	Turbomachinery	3	0	0	9
	Basket 3				
MED546	Conduction and Radiation	3	0	0	9
MED547	Convection and Two-Phase Flow	3	0	0	9
MED548	Heat Exchanger Design	3	0	0	9
MED549	Cryogenic Engineering	3	0	0	9
MED550	Combustion and Emission in I.C. Engines	3	0	0	9
	OPEN ELECTIVES (ANY TWO)				
MEO579	Computational Fluid Dynamics	3	0	0	9
MEO580	Measurements in Thermal Engineering	3	0	0	9
MEO581	Fundamentals of combustion	3	0	0	9
PRACTICALS AND OTHERS					

MEC551	CFD Lab	0	0	3	3
MEC552	Thermal Engineering Lab-III	0	0	2	2
	Total	**15**	**0**	**3**	**50**

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED538**	**Gas Dynamics**	3	0	0	9

Course Objectives
1. The aim of the course is to lay out the basic concepts and results for the compressible flow of gases. 2. Students can apply the principles of gas dynamics for the design of high speed vehicles, such as rockets, missiles and high speed aircraft.
Learning Outcomes
Upon successful completion of this course, students will: 1. have a broad understanding of the basic concepts of gas dynamics. 2. have a thorough understanding of Mach waves, shock waves and their relations. 3. be able to apply the principles of gas dynamics for predicting the aerodynamic characteristics of the in high speed vehicles.

Modules	Topics	Lecture hours	Learning outcomes
1	Review of Fundamentals: Concepts from Fluid Mechanics, Compressibility Thermodynamic concepts, Conservation equations, Stagnation state	4	To understand the basic concepts and elements of compressible flow
2	Compressible flow: Concept of Waves in fluid, Mach waves, Compression waves, Expansion fans, Differential equations for 1D flow	4	To understand the concepts of Mach waves, Compression waves, Expansion fans and differential equations for 1D flow
3	Basic Flow features: Isentropic flow, Shock waves, Stationary and Moving Shocks, Oblique Shocks, Bow Shocks, Expansion Fans, Normal Shock Concept, Normal Shock relations, Moving normal shocks Concept and theory, Oblique Shock	7	To understand the concepts of a shock wave, stationary and moving, Normal and oblique shocks, Normal/Oblique shock relations

	relations, Property variations		
4	Detached Shocks, Shock Reflections, Flow around bodies, Crocco's theorem, Cone flows, Shock expansion theory	7	To understand the concepts of detached shocks, shock reflections, Cone flows and shock expansion theory
5	Quasi-1D flow with area variations, Geometric Choking, Convergent Nozzles, CD Nozzles, Exit vs Stagnation pressure variation, shock wave reflections, Jet flows, Under expanded and over-expanded jet flows, Flow with Friction, Friction choking, Flow with heat addition, Thermal choking	10	To understand the concepts of QUASI-1D flows, Under expanded and over-expanded jet flows, Flows with friction and Flows with heat transfer
6	Prandtl Meyer Function, Supersonic wind tunnel, Shock Tube, Shock tunnel, Flow visualization, Basics of hypersonic flow	7	To understand the concepts of supersonic wind tunnel, Shock Tube and Shock tunnel

Text books:

1. Liepmann, H. W. and Roshko, A., Elements of Gas Dynamics, Dover Publications Inc., 2002.

2. John D. Anderson, Modern Compressible Flow: With Historical Perspectives, 3rd Edition, 2004.

References:

3. Oosthuizen, P. H. and Carscallen, W. E., Compressible Fluid Flow, McGraw-Hill international Edition, Singapore, 1st Edition, 2003.

4. Babu, V., Fundamentals of Gas Dynamics, Wiley-Blackwell, 2nd Edition, 2014.

5. Chapman A. J. and Walker W. F., Introductory Gas Dynamics, Holt, Reinhart and Winston, Inc., NY, USA, 1st Edition, 1971.

6. S. M. Yahya, Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, New Age International, 2018.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED539**	**Fundamentals of Aerodynamics**	3	0	0	9

Course Objectives
To illustrate and explain to students the basics principals and governing conservation equations and how these fundamentals can be applied to estimate aerodynamic forces and moments and to understand other related interesting problems.
Learning Outcomes
On successful completion of the course, the students will 1. Learn the fundamental principles of fluid mechanics and thermodynamics required to investigate the aerodynamics of airfoils, wings, and airplanes and other related problems; 2. Learn about the geometric features of airfoils, wings, and airplanes and how the names for these features are used in aerodynamics communications; 3. Explore the aerodynamic forces and moments that act on airfoils, wings, and airplanes and learn how we describe, estimate and compute numerically and theoretically these loads quantitatively in dimensional form and as coefficients; 4. Learn the reason behind induced drag and the formation of trailing edge vortices for a 3D finite wing and its relevance in other related problems occurring in nature; 5. Learn about the effects of compressibility, formation of shocks and expansion fans on the aerodynamic performances of streamlined, bluff bodies and the jet exhaust.

Modules	Topics	Lecture hours	Learning outcomes
1	Basic overview of aerodynamics; Aerodynamic forces and moments; Continuity, Momentum and Energy equations; Inviscid incompressible flow; Applicability of the Bernoulli's equation	5	Understanding of the basic overview of Aerodynamics, Ideas on aerodynamics moments and forces, Derivation on the continuity and momentum and energy equation, Ideas on the basics of inviscid incompressible flows, flow features, Ideas on the application of Bernoulli's equation

2	Incompressible flow in a low speed wind tunnel, Potential flows with source and doublet, Potential flow over a circular cylinder, Kutta-Joukowski theorem and conformal mapping	4	Basic ideas on the characteristics of the incompressible flow in a low-speed wind tunnel, Ideas on sources and doublets and their application to the potential flow over a circular cylinder, Ideas on Conformal Transformation and Kutta-Jukowski Theorem and its application to estimate the lift coefficient of a 2D airfoil section
3	Incompressible flow over airfoils and finite wings, Kutta condition, Kelvin's circulation theorem, Biot-Savart law, Helmholtz vortex theorem	5	Ideas on the incompressible flows over airfoil, The effects of finite wing, Ideas on downwash as a consequence of wing-tip vortex, Estimation of induced drag, Applicability of the Kutta-condition to fix the condition on the trailing edge, Ideas on the Kelvin's circulation theorem, Biot-Savart law and Helmholtz Theorems
4	Thin aerofoil theory; Prandtl's classical lifting line theory; Three dimensional source and doublet	7	Derivation of the thin airfoil theory and Prandtl's lifting line theory, Uses of these theories to estimate dependence of lift coefficient on the angle of attack, Introduction to the 3D source and doublet and extension of the 2D potential flow to 3D flow cases
5	Inviscid compressible flow, normal and oblique shocks, expansion waves, supersonic wind tunnels	7	Ideas on the inviscid compressible flow, normal and oblique shocks and Prandtl Meyer expansion fan and their reflection, General idea on the operational principals of supersonic wind-tunnel
6	Elements of hypersonic flow, Newtonian theory; Equations of viscous flow; Laminar and turbulent boundary layers	4	Ideas on the elements of hypersonic flows and Newtonian theory, Ideas on the equations of viscous flow, Basic concepts on the laminar turbulent transition in a boundary layer
7	Panel methods in aerodynamics, Flow separation and control, Jet flow and mixing layer	7	Ideas on the panel methods to estimate lift coefficients for arbitrary shaped bodies based on Potential flow theory, Basic ideas on flow separation and control, Jet flow and mixing layer

Text Books:

1. J. D. Jr. Anderson, Fundamentals of Aerodynamics, McGraw- Hill , 6^{th} Edition, 2016.

References:

1. J. J. Bertin, Aerodynamics for Engineers, Pearson Education, 4th Edition, 2002.

2. E. L. Houghton and N. B. Carruthers, Aerodynamics for Engg. Students, Arnold Pub., 3rd Revised Edition, 1988.

3. A. M. Kuethe, and C. Y. Chow, Foundations of Aerodynamics, Wiley, 5th Edition, 1998.

4. L. J. Clancy, Aerodynamics, Himalayan Books, 1st Edition, 2006.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED540**	**Fundamentals of Aeroacoustics**	3	0	0	9

Course Objectives
1. To understand the basics of flow induced noise via turbulent fluid motion / aerodynamic forces interacting with the surfaces since the area of aeroacoustics is an emerging one throughout the world. 2. It provides motivation to the students for pursuing higher studies / career related to aeroacoustics since many industries, universities and R&D sectors are working towards noise control.
Learning Outcomes
Upon successful completion of this course, students will: 1. have a broad understanding of basic concepts of aeroacoustics, governing equations. 2. have a thorough understanding of various noise sources, sound generation by flow. 3. be able to apply Lighthill's acoustic analogy, Ffowcs Williams and Hawking's theory for predicting the far-field acoustic radiations.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction: Background and definition of aeroacoustics, Linearity of acoustics, acoustics, vortical and entropy waves	4	To understand the background and definition of aeroacoustics, Linearity of acoustics
2	Conservation equations, Governing equations for 1-D and 3-D acoustics, Helmholtz resonator, Acoustic energy, intensity, Fourier analysis, power spectrum	4	To understand the Governing equations for 1-D and 3-D acoustics, Basic principle of Helmholtz resonator, Fourier analysis

3	1-D and spherically-symmetric acoustics in a medium at rest, Helhmholtz equation, Sound field due to monopole, dipole and quadrupole sources, their importance and relation with oscillating spheres	5	To understand the various sound sources, Helhmholtz equation
4	Green's function for wave equation, Green's formula, far-field approximations, compact sources and interferences	7	To understand the compact acoustic sources, far-field approximations
5	Acoustics of rigid solid boundaries: reciprocity theorem, Kirchhoff's formula, Analysis of sound due to moving sources	5	To understand the concepts reciprocity theorem, Kirchhoff's formula
6	Sound generation by flow: Lighthill's acoustic analogy, Ffowcs Williams and Hawking's theory	7	To understand the concepts of Lighthill's acoustic analogy and Ffowcs Williams and Hawking's theory for the predictions of flow induced noise
7	Interaction tones, buzz-saw noise, Aeolian tones: cavity noise, Experimental aeroacoustics: Anechoic chamber, calibration procedure, acoustic sensors, aero-acoustic measurements	7	To understand the concepts tonal and broadband noise, some basics of anechoic chamber, calibration procedure of anechoic chamber, aeroacoustic measurement techniques

Text books:

1. Goldstein, M. E., Aeroacoustics, McGraw-Hill, 1976.

2. Mueller, Thomas J. (Ed.), Aeroacoustic Measurements, Springer-Verlag Berlin Heidelberg, © 2002.

References:

3. Crighton, D. G., Basic principles of aerodynamic noise generation, Prog. Aerospace Sci., 16(1), 1975, pp. 31-96.

4. Howe, M. S., Theory of vortex sound, Cambridge University Press, 1st Edition, 2002.

5. Pierce, A. D., Acoustics, Acoustical Society of America, 1st Revised Edition, 1989.

6. Crighton, D. G., Dowling, A. P., Ffowcs Williams, J. E., Heckl, M. and Leppington, F. G., Modern methods in analytical acoustics,

Springer, 1st Edition, 1992.

7. L. E. Kinsler, A. R. Frey, A. B. Coppens and J. V. Sanders, Fundamentals of Acoustics, John Wiley, 4th Edition.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED541**	**Microfluidics**	3	0	0	9

Course Objectives
Microfluidics is an emerging and rapidly growing technology. The concept is widely applied to thermal management; MEMS based instruments and biological devices. In this course, students will learn principles of micro- and nano-scale transport phenomena. In addition, the course will also discuss about the micro-fabrication and few components of micro-system with some application.
Learning Outcomes
Upon successful completion of this course, students will: 1. have a broad understanding of microfluidics and its application. 2. have analytical and mathematical tools to handle microfluidics problem. 3. be able to understand the fabrication technique for making microfluidics devices.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction to microfluidics; Scaling analysis	3	Students will learn about the basics of microfluidics and its comparison with macro level fluid mechanics
2	Theory of microscale fluid flow: Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels. Hydraulic resistance	12	They will learn the basic fluids mechanics and mathematic used for the analysis of microfluidics.

	and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel		
3	Micro fabrication: Fabrication techniques for microdevices: photolithography, silicon-based micromachining, polymer-based micromachining	9	Students will learn about the different fabrication techniques for microfluidics devices
4	Components of microsystems- micropump, microvalve, micromixer, microparticle separator; Thermal transfers in microdevices; Micro- heat exchangers; Issues and challenges in microfluidic devices; Sensors and actuators; Biomicrofluidics, Lab-on-chip devices; Micro-total-analysis systems (μ-TAS)	12	In this module different microfluidics devices and their working will be discussed
5	Few applications of microfluidics: Drug delivery, Diagnostics, Bio-sensing	3	Recent applications of microfluidics for bio application will be discussed

Text Books:

1. Nguyen, N. T., Werely, S. T., Fundamentals and applications of Microfluidics, Artech House; 3rd Edition (January 31, 2019).

References:

2. Madou, M. J., Fundamentals of Microfabrication, CRC press.

3. Tabeling, P., Introduction to microfluidics, Oxford University Press Inc.

4. Kirby, B. J., Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED542**	**Finite Element Method in Thermal Engineering**	3	0	0	9

Course Objectives
1. FEM is going to be an indispensable numerical tool in the near future. The primary objective of this course is to acquaint the students with this powerful numerical method that enables them to solve simple as well as complex fluid dynamics and heat transfer problems with high accuracy. 2. To highlight the differences in FEM treatment of solid mechanics (Galerkin based) and fluid dynamics (Petrov-Galerkin based) problems.
Learning Outcomes
1. The students will develop the ability to model steady/unsteady heat conduction as well as convection-diffusion problems using FEM. 2. Relative to the conventional FEM ways of generating the assembled matrix and vector, the students will learn a different approach of formulating the global matrix and vector that is very conducive to computer coding. 3. According to the present curriculum, this course will be offered simultaneously with Computational Fluid Dynamics where FDM and FVM are mostly covered. After this FEM course, the connections/differences among these three compteting numerical tools will be very clear to the students.

Modules	Topics	Lecture hours	Learning outcomes
1	Concept of variational methods, concept of FEM, comparison with alternate methods such as, FDM and FVM	7	This introductory module will enable the students to have the basic flavour of early numerical methods that were developed as a suitable substitute of the analytical approach
2	Strong and weak forms of a differential equation, Galerkin finite-element method, weight and shape functions, element connectivity and assembly	5	After this module, the students will be able to generate the variational statement of a given PDE or ODE. Besides, they will be able to construct the basis functions and various arrays that aid in generating the global matrix and vector

3	Numerical integration, isoparametric elements, coordinate transformation, basic matrix equation solvers	6	This foundation module will enable the students to evaluate the element level matrix and vector entries via Gauss quadrature. The strength of FEM for problems involving complex geometry will be more apparent. This module will also familiarize the students with the role of linear algebra in solving fluid dynamics problems via FEM
4	FEM discretization of unsteady equations, implicit and explicit methods, implementation of EBC, NBC and convective boundary conditions	4	The students will be familiar with the trapezoidal rule to discretize an unsteady term via FDM. They will also learn to implement the boundary conditions via use of various arrays discussed in module II
5	Matrix and vector formation for one- and two-dimensional heat conduction problems, treatment of one-dimensional convection-diffusion equation using linear and quadratic elements	7	This module implements for a single-degree-of-freedom problem, the theory discussed in the previous modules. The students will be able to completely formulate and discretize the Laplace/Poisson equations in single or two-dimensions and one-dimensional convection-diffusion equation
6	Limitations of Galerkin method for flow problems, upwinding, Petrov-Galerkin method, Navier-Stokes equations: properties and limitations, coupled versus segregated formulation of Navier-Stokes equations, connectivity and assembly for equations with multiple degrees-of-freedom	5	This module will highlight the inability of the Galerkin formulation to accurately predict a flow field and will also suggest the ways to modify the Galerkin approach. The students will be able to generate the global matrices for problems with multiple unknowns
7	Coupled formulation of steady Navier-Stokes equations in two-dimensions using collocated arrangement.	5	After this conclusive module, the students are expected to successfully discretize the Navier-Stokes equations of motion using coupled approach in two-dimensions

Text books:

1. An introduction to the finite element method, J. N. Reddy, Tata McGraw-Hill Edition, 4^{th} Edition, 2019.

2. Finite element method for flow problems, J. Donea and A. Huerta, Wiley publication, 2003.

References:

3. The finite element method, T. J. R. Hughes, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, Dover Publications, 1st Revised Edition, 2000.

4. Fundamentals of the finite element method for heat and fluid flow, R. W. Lewis, P. Nithiarasu and K. N. Seetharamu, John Wiley & Sons, 2nd Edition, 2016.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED543**	**Solar Energy**	3	0	0	9

Course Objectives
Students can utilize the knowledge of this theoretical concept in solar based industries for manufacturing the collectors for capturing more and more energy from the Sun.
Learning Outcomes
Upon successful completion of this course, students will: 1. be able to design the flat plate solar air / water heater. 2. be able to design focusing type solar collector. 3. be able to use this solar energy concept for designing solar storage systems.

Modules	Topics	Lecture hours	Learning outcomes
1	Need of sources of renewable energy, Introduction to different sources of renewable energy, Solar Energy and Applications	3	Students will learn about renewable sources of energy
2	Basic concepts, Solar constant, Beam and diffused radiation	3	For understanding further topics, knowledge of solar constant is very important for the students
3	Flat plate and concentrating collectors, Liquid Flat Plate Collector, Flat Plate Solar Air Heater, Concentrating Collectors	8	Knowledge of different types of solar collectors are very important for capturing solar energy
4	Performance analysis of solar collector, Instantaneous collector efficiency	5	Collector efficiency is one of the important performance parameters for the solar collectors. Students will learn this terminology

5	Overall loss coefficient, Collector efficiency factor, Collector heat removal factor	4	Students will learn different losses during collection of energy through solar collectors
6	Concentration ratio, Tracking requirements, Thermal energy storages, Solar pond	10	Students will learn about concentrating solar collector. Also, they will learn about the storage the solar energy
7	Economic Analysis	4	Economics of solar energy utilization
8	Case studies: Performance test on CPC and Flat Plate collector	2	Students will do some case studies by conducting the experiments on CPC and Flat plate collector

Text books:

1. S. P. Sukhatme, Solar Energy - Principles of Thermal Collection and Storage, TMH, 3rd Edition, 2008.

References:

2. John A. Duffie and William A. Beckman, Solar Engineering for Thermal Process, Wiley and Sons, 1st Edition, 2013.

3. H. P. Garg, Solar Energy, 1st Revised Edition, 2000.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED544**	**Advanced Steam Power Plant**	3	0	0	9

Course Objectives
1. To impart knowledge dealing with computation aspects of Advanced Steam Power Plant. 2. This course is essential for design of Thermal power plant.
Learning Outcomes
1. Illustrate the fundamental principles and applications of thermal power plant system. 2. Obtain heating capacity, output power and efficiency by conducting test on vapour cycles. 3. Present the properties, applications and environmental issues of different coal. 4. Calculate performance at different loads for thermal power plant systems used for various applications. Operate and analyze the thermal plants.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction: Energy sources and scenario	2	Students will know the use of thermal properties in engineering and other applications
2	Power Plant Cycles – Reheat and Regenerative	10	An ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political ethical health
3	Supercritical – Coupled and Combined Cogeneration Plants	6	An ability to design a system and improve the output power of the thermal power plant
4	Exergy Analysis of Power Plant Cycles	2	An ability to identify, formulate and utilize maximum amount of energy
5	Coal, its properties and combustion	4	The understanding of coal properties and relative

			technical term combustion in thermal power plant
6	Analysis and seizing of Power Plant Components: Steam generator, Condenser, Cooling tower and other heat exchangers	7	Calculations of heating and cooling load, sensible heat and lateral heat in thermal power plant involve the usage of property equations framed earlier
7	Power plant economics and Energy audit	4	Known about the economics of the thermal power plant with relative the mathematical equation
8	Recent trends in Power Production	4	An ability to identify and formulate the thermal power plant in the current scenario

Text Books:

1. Principle of Energy Conversion by A. W. Culp, Tata McGraw-Hill.

2. Power Plant Technology by M. M. Elwakil, Tata McGraw-Hill.

References:

3. Applied Thermodynamics by T. D. Eastop and A. McConkey, ELBS.

4. Modern Power Plant Engineering by J. Weisman and R. Eckart, Prentice Hall.

5. Power Plant Engineering by P. K. Nag, Tata McGraw-Hill.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED545**	**Turbomachinery**	3	0	0	9

Course Objectives
1. To make the students accustomed with various turbomachines and related complex processes. 2. The provide knowledge of performance evaluation, operation and maintenance of rotodynamic machines.
Learning Outcomes
1. Knowledge of transport processes through the turbomachine passage. 2. Knowledge about the analytical, numerical and experimental tools for design, operation, performance evaluation. 3. Enabling the students to perform innovative researches in the area of turbomachines.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction, Classification of turbomachinery	1	To introduce the subject, various turbomachines, classifications and processes
2	Thermodynamics: Adiabatic flow through Nozzles and Diffusers. Work and efficiencies in Turbine and Compressor stages	8	Fundamentals about the thermodynamic analysis of the flow through nozzles and diffusers, and the corresponding analysis
3	Dimensional Analysis: Principle of Similarity, Incompressible and Compressible flow machines, Performance of Turbines, Compressors	6	To introduce the dimensional analysis of various flow machines
4	Axial flow Turbine and compressors: stage velocity diagram, enthalpy entropy diagram, stage losses and efficiency, Performance characteristics	7	An ability to identify, formulate and utilize maximum amount of energy

5	Centrifugal Pumps and Compressors: stage velocity diagram, enthalpy entropy diagram, optimum design at inlet, slip factor, stage losses and efficiency, Performance characteristics	6	The understanding of pumps and compressors, corresponding analysis, and performance evaluation
6	Radial Turbines: stage velocity diagram, enthalpy entropy diagram, stage losses and efficiency, Performance characteristics	5	The understanding of radial turbines, corresponding analysis, and performance evaluation
7	Hydraulic Turbines: Pelton turbine, Kaplan turbine, Francis turbine, effect of size on turbomachine efficiency, cavitation	6	The understanding of hydraulic turbines, corresponding analysis, and performance evaluation

Text Books:

1. S. M. Yahya, Turbines, Compressions & Fans, Tata McGraw-Hill, 2011.

2. S. L. Dixon and C. A. Hall, Fluid Mechanics and Thermodynamics of Turbo machinery, Elsevier, 2014.

References:

3. V. Ganesan, Gas Turbine, Tata McGraw-Hill, 3rd Edition, 2010.

4. M. Dubey, B. V. S. S. S. Prasad and Archana Nema, Turbomachinery, Tata McGraw-Hill, 2018.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED546**	**Conduction and Radiation**	3	0	0	9

Course Objectives
This is introductory course on conduction and radiation heat transfer. This course aims to provide fundamentals concepts and their application in conduction and radiation heat transfer. They will be learning different solution methods to handle the complex problem in conduction and radiation.
Learning Outcomes
Upon successful completion of this course, students will: 1. have a broad understanding of conduction and radiation heat transfer. 2. have analytical and mathematical tools to handle complex heat transfer problem. 3. be able to provide some basic solution to real life conduction and radiation heat transfer problems.

Modules	Topics	Lecture hours	Learning outcomes
1	Review of basic concepts: Introduction to heat transfer, Modes of heat transfer, Differential formulation of the heat conduction equation, Different types of boundary conditions, One dimensional steady state heat conduction with energy generation and variable thermal conductivity. Heat conduction for non isotropic materials, Extended surface: Variable area fins, Introduction to Bessel differential equation and Bessel function	6	Students will review the basic heat transfer. They will learn about steady state conduction and its application. Heat transfer enhancement by extended surface also will be discussed

2	Multi-Dimensional steady-state conduction: Sturm-Liouville Boundary-Value Problem, Orthogonality, separation of variable method, Non-homogeneous Boundary conditions: The method of superposition, 3-D analysis	4	Students will learn to handle multi-dimensional heat conduction and different mathematical approach for its analysis
3	Transient heat conduction: Introduction, Lumped capacity analysis: Improved lumped models, Time dependent Boundary Conditions: Duhamel's superposition integral. Transient heat flow in a semi-infinite solid: The similarity method, The integral method. Time periodic boundary condition conduction problems, Graphical method for conduction problems	6	Transient heat conduction and its analysis will be learned. Learning about time dependent boundary condition and solution.
4	Conduction with phase change: Introduction, The heat equation for moving boundary problems, Non-dimensional form of the governing equations and important governing parameters, Simplified Model: Quasi steady Approximation, Exact solutions: Stefan's solution, Neumann's solution.	7	Specific topics discussing about moving boundary problem and phase change will be analyzed.
5	Perturbation Solution: Introduction, Solution procedure; Perturbation solution examples: transient conduction with surface radiation, conduction with variable thermal conductivity. Introduction to heat conduction in porous media: Simplified heat transfer model	6	Conduction with porous media and perturbation solution will be learned in this module.
6	Review of radiation heat transfer, View factors, The crossed strings method, The inside sphere method, The unit sphere method, Radiant energy transfer through absorbing, emitting and scattering media. Radiative transfer equation (RTE), Beer-Lambert's Law, solution for the straight path, radiative heat flux, Equivalent beam length, Enclosure analysis in the presence of an absorbing or emitting gas.	10	Students will be able to analyze the radiation heat transfer. They will learn different techniques to evaluate view factor. They will also learn about gas radiation.

Text Books:

1. Latif M. Jiji., Heat Conduction, 3rd Edition, Springer, 2009.

2. M. F. Modest, Radiative Heat Transfer, Academic Press, 3rd Edition, 2013.

References:

3. E. R. G. Eckert and Robert M. Drake, Analysis of Heat and Mass Transfer, McGraw-Hill, 1st Edition, 1987.

4. Vedat S. Arpaci, Conduction Heat Transfer, Addison-Wesley series, 1st Revised Edition, 1966.

5. F. Incropera, D. J. Dewitt, T. Bergman and A. Lavine, Fundamentals of heat and mass transfer, Wiley & Sons Inc., 7th Edition, 2011.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED547**	**Convection and Two-Phase Flow**	3	0	0	9

Course Objectives
Advanced treatment of fundamental aspects of convection and two-phase heat transfer. Students pursuing research in the field of convection/two-phase flow can utilize the knowledge for finding new things in this area;
Learning Outcomes
Upon successful completion of this course, students will: 1. have a broad understanding regarding fundamental aspects of convection and two-phase heat transfer. 2. be able to offer ideas about how to analyze various multiphase problems.

Modules	Topics to be Covered	Lecture hours	Learning outcomes
1	Introduction to convection, Derivation of governing mass momentum and energy balance equations, Scale analysis and concept of heat line	3	Students will have concept on convection
2	Boundary layer concept in external flow: Forced convection heat transfer over a flat plate, velocity and thermal boundary layer, Scale analysis, Integral solutions, Similarity solutions	8	Students will have concept on flow over a flat plate
3	Internal forced convection: Hydrodynamic entrance length, Review of duct flow, Thermally and hydraulically developed flow through circular tube: uniform surface heat flux, uniform surface temperature, The Graetz problem	8	Students will have concept on Internal forced convection
4	Laminar boundary layer equations for natural convection,Boussinesq approximation, Scale	8	Students will have concept on natural convection

	analysis for high and low Pr number, Integral and similarity solutions, combined natural and forced convection (Mixed Convection)		
5	Film condensation along a flat plate, Introduction to two phase flow, Flow regimes for single and two component vertical and horizontal flow, Conservation equations based on homogeneous flow, drift flux model, separated flow model (multi-fluid model), Pool boiling curve, film boiling, flow boiling, Experimental methods for boiling and two-phase flow	12	Students will have concept on two phase flow, boiling, and condensation

Text Books:

1. Adrian Bejan, Convective heat transfer, John Wiley & Sons, 4th Edition, 2013.

2. W. M. Kays and M. E. Crawford, Convective heat and mass transfer, McGraw-Hill, 4th Edition, 2017.

References:

3. Louis Bermister, Convective heat transfer, 2nd Edition, 1993.

4. Latif M. Jiji., “Heat Convection”, Springer, 3rd Edition, 2009.

5. Patrick H. Oosthuizen and David Naylor, An introduction convective heat transfer, McGraw-Hill, 2nd Edition, 1990.

6. L. S. Tong, Boiling heat transfer and two phase flow, John Wiley & Sons, 1st Edition, 1965.

7. P. B. Whalley, Boiling, condensation, and gas-liquid flow, Oxford university press, 1st Revised Edition, 1999.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED548**	**Heat Exchanger Design**	3	0	0	9

Course Objectives
1. The objective of the course is to understand the thermal design procedures of different types of Heat Exchangers used is various industrial applications. To get familiarized to different types of standards, charts, templates, property tables, industrial practices etc. required for design of heat exchangers.
Learning Outcomes
1. have a broad understanding of different heat transfer correlations used in various applications. 2. learn the step by step procedure to design various types of heat exchangers. 3. learn to estimate heat transfer rates in heat exchangers under various operating conditions. 4. learn about the material selection and maintenance of heat exchangers.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction to Heat Exchangers, Classification of Heat Exchangers, Direct transfer type, Storage type, Direct contact type, Tubular, Plate and Extended surface H.Es, TEMA Nomenclature of Shell and Tube Heat Exchanger	4	Understanding different types of heat exchangers and their merits, demerits and applications
2	Basic Thermal and Hydraulic Relations in Heat Exchangers Design, Basic Principles of Thermal	6	Understanding the basic methodology for heat exchanger design calculations. To get familiar

	Design, The effectiveness-NTU Method, Thermal Hydraulic correlations for H.E Design, Shell side flow correlation		with various correlations required for design calculations and their applications.
3	The tube side correlations, Thermal Design of Shell and Tube heat exchangers: Kern's Method, Tinker Model, Divided Flow Method, Design considerations	8	Step-by-step design procedure for different approaches for designing shell and tube heat exchanger.
4	Effects of fouling, Design of Condensers and Evaporators, Types and choice of a condenser / evaporators, Heat Transfer coefficient and Pressure drop calculations	8	Learning the effects of fouling in heat exchanger design, Methodology and correlations required for designing condensers and evaporators,
5	Design procedure, Thermal Design of Compact Heat Exchangers, Flow arrangements and Surface Geometries, Heat Transfer and Friction factor data	6	Learning the methodology and correlations required for designing compact heat exchangers.
6	Calculation procedure of compact heat exchanger, Flow induced vibrations in H.E, Tube vibration, Vibration Damage patterns, Regions of tube failures, Heat Exchanger Materials and their manufacturing techniques	7	Learning different mechanisms for flow-induced vibrations and its effects, Learning materials and manufacturing techniques used for heat exchangers.

Text Books:

1. Sadik Kakac and Hongtan Liu, Heat Exchangers – Selection, Rating and Thermal Design, CRC press, 3rd Edition, 2012.

References:

2. A. P. Fraas and M. N. Ozisik, Heat exchanger Design, Wiley New York, 1989.

3. W. M. Kays, Compact Heat Exchanger, McGraw-Hill, New York, 1964.

4. D. Q. Kern, Extended Surface Heat Exchangers, McGraw-Hill, New York, 1st Edition, 1965.

5. G. Walker, Industrial Heat Exchangers-A Basic Guide, McGraw-Hill, New York, 1st Revised Edition, 1983.

6. D. Q. Kern, Process Heat Transfer, McGraw-Hill, New York, 1st Revised Edition, 2007.

7. S. K. Das, Process Heat Transfer, Narosa Publishing House, 2005.

8. Ramesh. K. Shah and Dusan. P. Sekulic, Fundamentals of Heat Exchanger Design, John Wiley and Sons, 2003.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED549**	**Cryogenic Engineering**	3	0	0	9

Course Objectives
To encourage the dissemination of information concerning low temperature processes, techniques, and bringing all those together in all discipline concern with the application of low temperature technologies.
Learning Outcomes
Upon successful completion of this course, students will: 1. be able to know the field of basic thermodynamics, heat transfer, fluids, materials and insulation in cryogenic engineering. 2. be able to know the different cryogenic liquefaction cycles.

Modules	Topics	Lecture hours	Learning outcomes
1	Basic thermodynamics and heat transfer, heat leak and pressure drop in cryogenic transfer lines, properties of cryogenic fluids, material properties at cryogenic temperatures, cryogenic insulations	8	Introduce the students to the field of basic thermodynamics, heat transfer, cryogenic fluids, materials and insulation in cryogenic engineering
2	Liquefaction Cycles: Carnot liquefaction cycle, Joule Thomson Effect, Linde Hampson Cycle, Claudes Cycle, Helium Refrigerated Hydrogen Liquefaction Systems	8	Students will learn different cryogenic liquefaction cycles
3	Cryogenic Refrigerators: J. T. Cryocoolers, Stirling Cycle Refrigerators, G. M. Cryocoolers, Pulse Tube Refrigerators	8	Students will learn different cryogenic refrigerators
4	Cryogenic Instrumentation: strain, displacement,	7	

	pressure, flow, liquid level, density and temperature.		Students will learn basic instruments used in cryogenic engineering
5	Cryogenic Equipment: compressor, pumps, expansion engines, valves, heat exchangers, storage, transfer of liquefied gases.	8	Students will learn basic components used in cryogenic engineering

Text Books:

1. Cryogenic Engineering, Klaus D. Timmerhaus, Richard Reed, Springer, New York, 2010.

2. Fundamentals of Cryogenic Engineering, Mamata Mukhopadhyay, PHI Learning Pvt. Ltd., 2010.

References:

3. Cryogenic Systems, Randall F. Barron, McGraw-Hill, 1985.

4. Cryogenic Heat Transfer, Gregory Nellis and Randall F. Barron, CRC Press, 1999.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED550**	**Combustion and Emission in I.C. Engines**	3	0	0	9

Course Objectives
1. To broaden the perspectives of Combustion and thereby Emission of IC Engines that the students were introduced to in their undergraduate course of Automobile Engineering. 2. To understand the process of combustion of engines and how the process is different from normal daily life combustion process. 3. To introduce advanced details that will increase the curiosity, and therefore improve the ability to explain the combustion process through physics supported by mathematical analysis.
Learning Outcomes
1. Students will understand the combustion thermo-chemistry, mass transfer and flames, which will be needed for their master's research. 2. Strong foundation of the combustion processes and flame physics. 3. Understanding of the close coupling between combustion and emission process of IC Engines.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction, Engine classifications - Engine components - S.I. Engine operation – C.I. Engine operation – Relative merits and demerits	3	Recapitulation of the IC Engine processes, components, operations, and emissions, which have been already taught in the undergraduate course. The module is to guide the students towards the engine combustion process
2	Engine performance parameters	5	This important module will enable the students to understand the engine performance parameters and the evaluation of those parameters

3	Fuels, Desirable properties – SI engine fuels – CI engine fuels - Alternative fuels – Alcohols - CNG – LPG – Hydrogen - Biodiesels – Biogas - Dual fuel operation	4	The students will be acquainted with various fuels, conventional and non-conventional, which are used in engines
4	Combustion in SI Engines, Introduction – Thermodynamic Analysis - Stages of combustion in SI Engine - Flame front propagation– Factors influencing flame speed - Rate of pressure rise – Analysis of cylinder pressure data – Heat release analysis - Cyclic variations in combustion, partial burning and misfire – Abnormal combustion and knocking – Effects of detonation - Effect of engine variables on detonation – SI Engine combustion chamber design principles – Types of combustion chambers	8	The module introduces the students to the combustion process that occurs inside various SI engines and how the process governs the generations of various emissions
5	Combustion in CI Engines: Introduction – Stages of combustion in CI Engine – Ignition delay – Factors effecting ignition delay – Knocking in CI Engine – Factors affecting knocking	7	The module introduces the students to the combustion process that occurs inside various CI engines and how the process governs the generations of various emissions
6	Types of Diesel Combustion systems – Direct injection systems - Indirect injection systems, comparison of combustion Systems - Combustion in direct injection multi spray – Analysis of cylinder pressure data - Heat release analysis	6	This module focuses on various injection systems that exists in CI engines and how the combustion process and the heat release is related for those systems
7	Emission, Pollution Norms- Types of pollutants, Measurement of Emissions, Exhaust gas treatment	6	The students will be accustomed with the emission norms, and how to measure and treat the emissions in real life

Text Books:

1. John B. Heywood, Internal Combustion Engine Fundamentals, McGraw-Hill Education; 1st Edition, 2017.

2. Stephen R. Turns, An Introduction to Combustion: Concepts and Applications, McGraw-Hill Education; 3rd Edition, 2017.

References:

3. E. F. Obert, Internal Combustion Engine and Air Pollution, Harper and Row Publishers, 1st Edition, 1973.

4. V. L. Maleeve, Internal Combustion Engines, McGraw-Hill Book Company, 1st Edition, 1945.

5. Colin R. Ferguson and Allan T. Kirkpatrick, Internal Combustion Engines, Wiley publishers, 1st Edition, 2000.

6. V. Ganesan, Internal Combustion Engines, Tata McGraw-Hill, 4th Edition, 2013.

7. H. N. Gupta, Fundamentals of Internal Combustion Engines, PHI, New Delhi, 2nd Edition, 2015.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**MEO579**	**Computational Fluid Dynamics**	3	0	0	9

Course Objectives
1. The prime objective of this course is to provide the students with in depth understanding of the computational approach for modeling and solving fluid dynamics as well as heat transfer problems. 2. To enable the students to mathematically represent a physical phenomenon, so that they can generate a mathematical model and finally, a numerical statement of a given problem and solve the problem via implementation of the theoretical knowledge gained. 3. To make the students initially believe and then understand that many of the results in heat transfer/fluid flow that they have studied in undergraduate/post-graduate courses can be generated accurately by themselves using CFD.
Learning Outcomes
1. The students will be familiar to a powerful tool for solving flow and heat transfer problems. This experience will enable them to numerically model a thermo-fluids problem using FDM and FVM. 2. The students will have the feel of the essential role the matrix algebra plays in approximate computations of ODEs and PDEs. 3. The students will be more inclined towards computer programming which will turn out to be very helpful in their Masters research and thereafter.

Modules	Topics	Lecture hours	Learning outcomes
1	Review of governing equations for conservation of mass, momentum and energy in primitive variable form	3	After this revision module, the students will be able to derive the conservation equations using Reynolds transport theorem and will also be able to interpret each equation

2	Mathematical behaviour of the conservation equations, equilibrium and marching problems	3	This important module will enable the students to distinguish given equations based on their characteristics (mathematical nature) and also to choose later, the appropriate differencing schemes as applicable
3	The finite difference method (FDM) and the variational methods, discretization, comparison of finite difference method, finite volume method (FVM) and finite element method (FEM)	2	The students will be acquainted with the brief history of development of the three basic discretization techniques as well as foundation of discretization
4	Review of Taylor's series, implicit, explicit and semi-implicit schemes, alternate direction implicit method	6	This module deals with the foundation of FDM; the students will be able to logically approximate a derivative and a differential equation
5	Convergence, stability analysis of a numerical scheme	4	This module will provide the concept of numerical error and guidelines for using or not using a differencing scheme while solving a CFD problem
6	Solution of linear matrix equation system and programming	2	This module will familiarize the students with the role of linear algebra in solving fluid dynamics problems
7	Application of FDM in one- and two dimensional steady and unsteady heat conduction and computer programming, artificial viscosity, upwinding	5	Practical implementation of all the topics covered up to module VI, introduction to numerical diffusion and CFD in fluid flow, students will be able to differentiate between CFD in heat conduction and CFD in fluid dynamics
8	Stream function-vorticity formulation	3	The students will learn the alternate flow equations as well as their solution methods used in early days of numerical treatment of flow problems
9	The finite volume method in orthogonal and non-orthogonal meshes, Green-Gauss theorem, application of FVM for heat conduction and convection-diffusion problem	7	The students will be able to discretize a given equation via direct integration on orthogonal and non-orthogonal meshes. This module will make the limitations of FDM more obvious to the students
10	Implementation of SIMPLE algorithm in two dimensions, Introduction to commercial package ANSYS-FLUENT	4	The students will have the flavour of a segregated fluid flow solver. In this context, they will learn the difficulties posed by the nonlinear convective terms and coupling between pressure and velocity. Thus,

			they can appreciate the depth and involvement in numerical treatment of a flow problem compared to a heat conduction problem

Text Books:

1. John D. Anderson, Computational Fluid Dynamics The basics with applications, McGraw-Hill Education, 1st Edition, 2017.

References:

2. Richard H. Pletcher, John C. Tannehill and Dale A. Anderson, Computational Fluid Mechanics and Heat Transfer, CRC Press, 3rd Edition, 2012.

3. Joel H. Ferziger and M. Peric, Computational Methods for Fluid Dynamics, Springer, 3rd Edition, 2002.

4. Clive A. J. Fletcher, Computational Techniques for Fluid Dynamics, Springer, 1st Edition, 1988.

5. T. J. Chung, Computational Fluid Dynamics, Cambridge University Press, 2nd Edition, 2010.

5. K. Muralidhar and T. R. Sundararajan, Computational Fluid Flow and Heat Transfer, Narosa Publishing House, 2nd Revised Edition, 2003.

6. S. V. Patankar, Numerical Heat Transfer and Fluid Flow, CRC Press, 1st Edition, 1980.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**MEO580**	**Measurements in Thermal Engineering**	3	0	0	9

Course Objectives
Aims to provide the fundamental knowledge of experimental methods in the field of fluid mechanics and heat transfer which will help the students while performing real time experiments and also to understand their applications in real life problems.
Learning Outcomes
Upon successful completion of this course, students will be able: 1. to understand the various measurement techniques and errors associated with measurement analysis. 2. to determine uncertainty in the measurement analysis. 3. to understand about the different measuring devices like Hot wire anemometer, Laser Doppler velocity meter, Capillary method, Saybolt viscometer, Manometer, Pirani gauge, Ionization gauge, Dynamic response of a U-tube manometer, Resistance Thermometer, Pyrometry, etc. 4. to apply the knowledge of fixing permissible error in a measuring device and the importance of considering error while calculating different physical parameters.

Modules	Topics	Lecture hours	Learning outcomes
1	Basic concepts of measurements, Different types of errors in measurements, Statistics in Measurements, Uncertainty in measurements, Linear regression, Parity plot	8	To understand the different types of errors associated with measurement analysis and the determination of uncertainty in measurements
2	Temperature measurements: Thermometer, thermocouples, Temperature measurement in the solid, Measurement of Transient temperature, Resistance	8	To understand the theory and working principles of different instruments used for temperature measurements

	Thermometer, Pyrometry		
3	Measurements of Heat Flux, Interferometry, Differential Interferometer	3	To understand the theory and working principles of different instruments used for heat flux measurements
4	Thermal conductivity measurement: Guarded hot plate apparatus, heat flux meter .	3	To understand the theory and working principles of different instruments used for the thermal conductivity measurements
5	Pressure measurements: Manometer, Vacuum measurements, Pirani / Ionization gauges, Dynamic response of a U-tube manometer	7	To understand the theory and working principles of different apparatus used for the pressure measurements
6	Flow and velocity measurements: Different methods of incompressible and compressible flow measurements, Pitot static tube, Hot wire anemometer, Ultrasonic method, Doppler effect, Vortex Shedding Flow meter, Laser Doppler velocity meter	7	To understand the theory and working principles of different instruments used for the measurements of flow velocity
7	Viscosity Measurement: Capillary method, Torque method, Saybolt viscometer	3	To understand the theory and working principles of different instruments used for viscosity measurements

Text Books:

1. J. P. Holman, Experimental Methods for Engineers, McGraw-Hill Science Engineering; 8th Edition, 2011.

2. S. P. Venkateshan, Mechanical Measurements, John Wiley & Sons and Ane Books Pvt. Ltd., 2nd Edition, 2015.

References:

3. S. M. Yahaya, Compressible Flow, New Age International (p) Ltd., 5th Edition, 2016.

4. E. O. Doebelin, Measurement systems, Application and Design, Tata McGraw-Hill, 5th Edition, 2007.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**MEO581**	**Fundamentals of Combustion**	3	0	0	9

Course Objectives
1. The course is to familiarize the students with the basics of combustion process, the equations involved, flame and its propagation, spray combustion, etc. 2. The subject is important for various automobile and oil industries, so fundamental knowledge will help in getting jobs in these industries.
Learning Outcomes
Upon successful completion of this course, students will be able: 1. to understand basics of combustion process, the equations involved, Droplet evaporation, Atomization, Spray Combustion. 2. to understand governing equations for a reacting flow, general characteristics of combustion, volumetric combustion. 3. to get jobs in automobile/oil industries.

Modules	Topics	Lecture hours	Learning outcomes
1	Fuels and their properties, Review of basic thermodynamics and gaseous mixtures	3	To understand the different types of fuels and their properties, review of basic thermodynamics
2	Combustion Thermodynamics; Stoichiometry, First and second Laws of thermodynamics applied to combustion; Heat, temperature and composition products in equilibrium	5	To understand the first and second laws of thermodynamics applied to combustion
3	Mass transfer basics	6	To understand the basics of mass transfer
4	Fundamentals of combustion kinetics	4	To understand the basics of combustion kinetics
5	Governing equations for a reacting flow, General	6	To understand the basic equations for reacting

	characteristics of combustion, volumetric combustion, explosion and detonation		flows, general characteristics of combustion, explosion / detonation
6	Laminar flame propagation; deflagration, premixed flame burners, theories, Flammability limits, partial premixing and quenching of laminar flames, Ignition, Flame stabilization, Gas jets and combustion of gaseous fuel jets, Turbulent premixed and non-premixed flames	8	To understand the theory of laminar flames, flame propagation, Flame stabilization, Turbulent premixed and non-premixed flames
7	Droplet evaporation and combustion, Atomization, Spray Combustion, Solid fuel combustion	7	To understand the theory of droplet evaporation, spray combustion

Text books:

1. Stephen R. Turns, An Introduction to Combustion: Concepts and Applications, McGraw-Hill Education; 3rd Edition, 2017.

References:

2. Kenneth Kuo, Principles of Combustion, John Wiley, 2nd Edition, 2005.

3. Irvin Glassman, Combustion, Academic Press, 5th Edition, 2014.

4. F. A. Williams, Combustion Theory, ABP, 2nd Edition, 1994.

5. H. S. Mukunda, Understanding Combustion, Macmillan India.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**MEC551**	**CFD LAB**	0	0	3	3

List of practicals
1. Introduction to ANSYS-FLUENT 2. Construction of simple and complex meshes 3. Solution of heat conduction problem in two-dimensions 4. Study of lid-driven cavity flow problem in two-dimensions 5. Unsteady flow past a fixed circular cylinder and an aerofoil at different Reynolds numbers, attempt to predict noise radiation 6. Computer coding for matrix equation solvers 7. Structured mesh generation by computer coding - algebraic method and method of transformation 8. Coding for unsteady heat conduction using explicit, implicit and semi-implicit schemes 9. Finite difference coding for lid-driven cavity problem using stream function-vorticity method 10. Preparation of report based on lab work and viva-voce.

Course Type	Course Code	Name of Course	L	T	P	Credit
DC	**MEC552**	**THERMAL ENGINEERING LAB-III**	0	0	2	2

List of practicals
1. Experiment on VCR Engine using diesel 2. Experiment on VCR Engine using petrol 3. Experiment on computerized 4-S ,4 Cylinder Petrol Engine 4. Experiment on computerized 4-S ,4 Cylinder Petrol Engine using blended fuel 5. Experiment on exhaust gas analyzer and engine smoke meter 6. Experiment on solar air heater 7. Experiment on summer air conditioning Test-Rig 8. Experiment on vapour compression refrigeration system 9. Experiment on vapour absorption refrigeration test – rig 10. Experiment on vortex tube refrigeration system

3RD Semester					
Course No.	**Course Name**	**L**	**T**	**P**	**CH**
MEC 569	Thesis Unit 1	0	0	0	9
MEC 570	Thesis Unit 2	0	0	0	9
MEC571	Thesis Unit 3	0	0	0	9
MEC 572	Thesis Unit 4	0	0	0	9
	Total	**0**	**0**	**0**	**36**

4th Semester					
Course No.	**Course Name**	**L**	**T**	**P**	**CH**
DEPARTMENTAL ELECTIVES/OPEN ELECTIVES (ANY TWO)					
MED573	Advanced Optimization Techniques	3	0	0	9
MED574	Research Methodology and Statistics	3	0	0	9
MEO 582	Flow and Transport Phenomena Through Piping System	3	0	0	9
MEO 583	Design of Thermal systems	3	0	0	9
MEO 584	Waste Heat Utilization	3	0	0	9
MEC 575	Thesis Unit 5	0	0	0	9
MEC 576	Thesis Unit 6	0	0	0	9
	Total	**0**	**0**	**0**	**36**

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED573**	**Advanced Optimization Techniques**	3	0	0	9

Course Objectives
1. To understand theory of different optimization methods to solve various types of engineering problems. 2. To understand physical engineering problem and to construct mathematical formulation towards solving it by selecting proper optimization techniques. 3. To understand both computer programming and heuristic approaches to solve optimization problems.
Learning Outcomes
Upon successful completion of this course, students will: 1. have a broad understanding on formulation of engineering optimization problem, especially for mechanical engineering. 2. have an understanding about solving the real life/ industrial /engineering/ environmental/ social problems using conventional optimization methods, that helps to take decision. 3. be able to write MATLAB code for single and multivariable engineering problems. 4. be able to understand and write MATLAB code for nontraditional optimization technique like GA, ANN, fuzzy logic to solve different engineering problems with single objective function and multi-objective function.

Modules	Topics	Lecture hours	Learning outcomes
1	Basic Concepts: optimization problem formulation	2	Understanding the types and basic concept of engineering optimization problem formulation. Especially real life / industrial / engineering / environmental / social problems
2	Single variable optimization algorithms: Exhaustive	6	This unit discuss about different types of classical

	search method, bounding phase method, Interval halving method, Fibonacci method, golden search method, Newton Rapshon method, bisection method, secant method. Formulation of engineering problem with single variable. Computer programming to solve the single variable problem		single variable optimization algorithms. Student will learn to write MATLAB code for these algorithms also
3	Multivariable optimization algorithms: Unidirectional search, direct search methods: simplex search, gradient based methods: Cauchy's Steepest Descent method Formulation of engineering problem with multiple variable. Computer programming to solve Multivariable optimization algorithm	8	This unit discusses about different types of classical multivariable unconstrained optimization algorithms. Student will learn to write MATLAB code for these algorithms also
4	Constrained optimization algorithms: Linear programming, nonlinear programming penalty function method, method of multipliers, sensitivity analysis, direct search for constrained minimization. Formulation of engineering problem with constrained multiple variable. Related computer Programming.	6	Students will learn constrained optimization algorithms and their computer programming
5	Nontraditional optimization: Introduction to Genetic algorithm (GA), Artificial Neural Network (ANN), fuzzy logic etc with single objective function. Computer programming, other evolutionary algorithms. Formulation of engineering problem and solve with Nontraditional optimization.	9	This unit demonstrates basics of Nontraditional optimization techniques. Use of Nontraditional optimization like GA, ANN, fuzzy logic with single objective function to solve different engineering problem
6	Multi-Objective Optimization: Introduction to linear and nonlinear multi-objective problems, Use of Evolutionary Computations to solve multi objective optimization with computer programming in MATLAB	8	This unit demonstrates Nontraditional optimization techniques to solve different engineering problem with multi objective function

Text Books:

1. Deb, K., Optimization for engineering design: algorithms and examples, Prentice Hall of India, New Delhi, 2^{nd} Edition, 2012,

References:

2. Deb, K., Multiobjective optimization using evolutionary algorithm. Wiley. 1st Edition, 2001.

3. Rao, S. S., Engineering Optimization: Theory and Practice, Wiley, 3rd Edition, 2014.

4. Ravindran, A., Ragsdell, K. M. and Reklaitis, G. V., Engineering Optimization: Methods and applications, Wiley, 2nd Edition, 2013.

5. Rardin, Ronald L., Optimization in operations research, Prentice Hall.

Course Type	Course Code	Name of Course	L	T	P	Credit
DE	**MED574**	**Research Methodology and Statistics**	3	0	0	9

Course Objectives
To illustrate to the students a) the basic concepts of research, b) how a scientific research problem has to be formulated and tackled and c) important statistical tools necessary to analyze the collected data for a meaningful research outcome.
Learning Outcomes
Upon successful completion of this course, students will: 1. learn various types of research process, methodologies to identify, design and execute a research problem based on scientific and statistical tools. 2. learn various types of sample design techniques and its classification, characteristics of a good sample design and how to select a sampling procedure for data collection. 3. learn various types of measurement scales, sources of error in measurement and technique of developing measurement tools to evaluate the collected data. 4. learn various methods of data collection and the reliability and validity of the collected data. 5. learn various ways to prepare and present report for dissemination of research outcome. 6. learn various statistical tools necessary for designing a sample, analyzing the data and making scientific conclusion(s) out of the collected data to arrive at a research outcome.

Modules	Topics	Lecture hours	Learning outcomes
1	Research Process, Types of Research, Problem identification, Hypotheses formulation	5	Basic ideas on research processes, Definition of various types of research, Knowledge on what constitute a research and how to identify a research problem, Knowledge on the formulation of

			hypothesis for research
2	Research Design: General Designs of Research, Randomized and Correlated Groups Design	5	Meaning of research design, Ideas on the need for research design, Knowledge on the features of a good research problem design, Important concepts relating to research design, Ideas on different research design methodologies, Ideas on the basic principles of experimental designs.
3	Sampling Design, Measurement and Scaling, Methods of Data Collection, Reliability and Validity	5	Ideas on the Implications of a Sample Design and its classification, Knowledge on the criteria of selecting a sampling procedure and characteristics of a good sample design, Ideas on measurement scales and sources of error in measurement, Knowledge on technique of developing measurement tools, Ideas on the meaning of scaling and important scaling techniques, Ideas on the methods of data collection and the reliability and validity of the collected data.
4	Data Presentation and Report Preparation, Introduction to Qualitative and Quantitative Research Methods	3	Ideas on Data presentation and report preparation techniques, Sensitizing the students on the very important issues of plagiarism, Preliminary ideas on the qualitative and quantitative research methodologies and their mutual difference.
5	Frequency Distribution, Presentation of Data, Measures of Central Tendency, Measures of Dispersion, Skewness	3	Ideas and knowledge on frequency distribution, cumulative frequency distribution, constructing histograms, Knowledge on the measures of central tendency (Mean, Median and Mode), Various measures of dispersion of the data.
6	Probability Distributions, Discrete and continuous random variable, Binomial, Poisson, Normal and Standard Normal distributions	6	Learn about Experiment, Outcomes, and Sample Space, Calculation of Probability, Ideas on Marginal and Conditional Probabilities, Learn about Mutually Exclusive, Independent and Complementary Events, Learn about Bay’s Theorem, Learn about discrete and continuous random variables and how to calculate their mean and standard deviation, Learn about Binomial, Poisson, Normal and Standard

			Normal distributions.
7	Sampling and Estimation, Sampling Distribution, Estimation of the mean and proportion, Hypothesis tests about the mean and proportion of a population, t-test and z-test, Estimation and hypothesis testing about two different populations.	6	Learn about sampling and estimation methods, hypothesis testing regarding the properties of the population from the sample statistics (sample mean and variance), Learn about Student's t-distribution and z-distribution and t-test and z-tests, Knowledge on estimation and hypothesis testing about two different populations
8	Hypotheses testing: χ^2 test, Analysis of Variance, Correlation and Regression analysis.	6	Learn about the Chi-Square distribution, Goodness-of-Fit test, Learn about making contingency tables, Learn about testing independence or homogeneity of populations, Learn to infer about the population variance, F-Distribution and one-way ANOVA, Learn about simple linear regression models and analysis.

Text Books:

1. Research Methodology - Methods and Techniques, C. R. Kothari and G. Garg, New Age International (P) Limited Publishers, 4th Edition, 2019, New Delhi.

2. Applied Statistics and Probability for Engineers, D. C. Montgomery and George C. Runger, 6th Edition, 2016.

References:

3. Research Methodology: A Step-by-Step Guide for Beginners, R. Kumar, SAGE Publications Ltd; 5th Edition, 2018.

4. Introductory Statistics, Prem S. Mann, 7th Edition, John Wiley and Sons Inc., 2010, Danvers, MA.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**MEO582**	**Flow and Transport Phenomena Through Piping System**	3	0	0	9

Course Objectives
1. To study transport of fluids in pipe. 2. To study about the components of piping system. 3. To study different application of piping system in agriculture, drainage, drinking and other industry applications.
Learning Outcomes
Upon successful completion of this course, students will: 1. have a broad understanding about fluids properties flowing through pipeline and transport theory. 2. have an understanding about the application of piping system in different field. 3. be able to use soft techniques to solve fluid distribution problem through pipe network. 4. be able to understand reasons behind erosion and corrosion occurred in pipeline and their remedy

Modules	Topics	Lecture hours	Learning outcomes
1	Basic Concepts: Conservation of mass, energy, momentum, second law of thermodynamics, unit and dimensions, fluid properties in perspective.	6	Understanding basic concept of fluid properties and laws of thermodynamics.
2	Introduction to Transport phenomenon, Momentum transport: Viscosity and mechanisms of Momentum transport, velocity distribution in laminar and turbulent flow, Energy Transport, Mass Transport.	9	Understanding the transport phenomenon through pipe.
3	Transport of fluids in piping system: pipe flow,	9	Understanding piping system components and their

	noncircular conduits, economic pipe diameter, various fittings, Non-Newtonian fluids, pumps and compressors, pipe network problems. Solve pipe network problem using BENTLEY HAMMER software.		design aspects.
4	Applications: Pipelines for water conveyance and drainage: Materials, Specifications and industry standards, Available sizes, system of units, corrosion, Fluid and Gas in Pipelines: Governing Factors, Slurry Transport: Rheometry and Rheological Models, Turbulent Flow of Non-Newtonians, Effects of Solids Concentration, Heat pipes: heat transfer and fluid flow theory.	9	Understanding different application of piping system in agriculture/drainage/industry, etc, and the flow characteristics.
5	Thermodynamics of corrosion. Fundamentals and application of corrosion theories, interaction of corrosion with erosion. Corrosion Control-Design improvement.	6	Understanding different problems arises due to flow in pipeline and the remedies.

Text Books:

1. Ron Darbyand, Raj P. Chhabra, Chemical Engineering Fluid Mechanics, CRC Press; 3rd Edition, 2016.

References:

2. Bird, R. B., Stewart, W. E., Lightfoot, E. N. and Klingenberg, D. J., Introductory Transport Phenomena, Wiley, 2015.

3. Christie J. Geankoplis, Transport process and unit operations, Prentice-Hall International, University of Minnesota, 3rd Edition, 1993.

4. Bird, Stewart, Lightfoot, Transport Phenomena, Wiley, 2nd Edition, 2002.

5. W. M. Deen, Analysis of Transport Phenomena, Oxford University Press, 2nd Edition, 2012.

6. E. L. Cussler, Diffusion: Mass Transfer in Fluid Systems, 3rd Edition, 2009.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**MEO583**	**Design of Thermal systems**	3	0	0	9

Course Objectives
1. The objective of the course is to equip the students with the techniques to design, simulate and optimize different thermal systems. 2. It enables the students to optimize the design of the thermal systems.
Learning Outcomes
Upon successful completion of this course, students will: 1. be able to utilize his knowledge of thermodynamics, heat transfer, and fluid mechanics in design of integrated thermal system. 2. be able to perform a thermal system simulation and solve for a workable solution using the method of successive substitution. 3. have a broad understanding formulation of engineering optimization problem, especially for thermal systems. 4. evaluate thermal systems based on life-cycle economics.

Modules	Topics	Lecture hours	Learning outcomes
1	Thermal system design, Design objectives, Principles of thermal design	6	This chapter will make the student understand the requirement, steps involved and to formulate a design problem. This chapter will also recapitulate the basic principles of heat transfer, thermodynamics and fluid flow which are widely used in this course.
2	Regression and curve fitting, System simulation (Successive substitution-Newton Raphson method)	8	To learn both linear and non-linear regression analysis and to develop different correlations based on the experimental results and to use the same for complete system simulation of complex thermal

			systems using various numerical root finding techniques.
3	Modelling of systems. Methods of optimization, Lagrange multipliers, Dynamic programming, Geometric programming, Linear programming	12	This module discusses about the different optimization techniques and makes the student well equipped to generate an objective function and the appropriate constraints for a complete thermal system design problem.
4	Economic consideration	6	This module will to make the student conversant with economic analysis of any engineering system with a view to arrive at a cost effective system.
5	Case studies, Examples applied to heat transfer problems and energy systems such as gas and steam power plants, refrigeration systems, heat pumps and so on	7	This module will help students in applying their understanding on design and optimization of thermal system to various complex systems of process industry, tri-generation units etc.

Text Books:

1. W. F. Stoecker, Design of thermal systems, Tata McGraw-Hill, 3rd Edition, 2011.

References:

2. Yogesh Jaluria, Design and Optimizations of Thermal systems 2nd Edition, CRC Press.

3. C. Balaji, Essentials of Thermal System Design and Optimization Ane Books Pvt. Ltd, 2nd Edition, 2007.

4. Adrian Bejan, George Tsatsaronis and Michael Moran, Thermal Design and Optimization, John Wiley and Sons, 1st Edition, 1995.

5. L. C. Burmeister, Elements of thermal fluid system design, Prentice Hall, 1st Edition, 1997.

Course Type	Course Code	Name of Course	L	T	P	Credit
OE	**MEO584**	**Waste Heat Utilization**	3	0	0	9

Course Objectives
1. Studies from various industries suggest that 20 to 50% of industrial energy input is lost as waste heat, which may be in the form of hot exhaust gases, heat lost from hot equipment and surfaces, etc. 2. Designed to make the students conversant with various methods of waste heat recovery that has been employed by the industry.
Learning Outcomes
Upon successful completion of this course, students will: 1. To be able to design power plant based on waste heat recovery. 2. To be able to design refrigeration and air conditioning system using solar energy. 3. To be able to design different thermal storage systems.

Modules	Topics	Lecture hours	Learning outcomes
1	Introduction to different sources of waste heat, industrial waste heat Importance of Waste Heat Recovery, Review of Thermodynamics – Introduction to First and Second Laws	4	Understanding about waste heat and industrial waste heat
2	Power Plant Cycles - Modification of Rankine cycle, Energy Cascading, Combined Cycle, Combined Gas Turbine-Steam Turbine Power Plant, Heat Recovery Steam Generators	8	For understanding further topics, students will learn different thermodynamic cycles
3	Direct conversion technologies – MHD-Steam power, Thermoelectric Generators, Thermionic	8	Students will learn different types of energy

	conversion, solar energy conversion, Thermo-PV		conversion systems
4	Energy Storage Techniques – Pumped hydro, Compressed Air, Flywheel, Superconducting Magnetic storage Thermal storage (Sensible & Latent), Battery, Chemical Energy Storage, Fuel cells	8	Students will learn different storage systems
5	Utilization of waste heat in organic Rankine cycle engines, in refrigeration and air-conditioning systems	5	Understanding about utilization of waste heat in refrigeration and air-conditioning systems
6	Waste Heat recovery systems: Heat Exchangers, Waste heat boilers, Heat Pipes, Fluidized bed waste heat recovery systems	6	Different types of waste heat recovery systems will be discussed

Text books:

1. P. K. Nag, Power Plant Engineering, Tata McGraw-Hill, 4th Edition, 2014.

2. S. Sengupta (Editor) and S. S. Lee (Editor)**:** Waste Heat: Utilization and Management, Springer, 1st Edition, 1983.

References:

3. Robert Goldstick and Albert Thumann, The waste heat recovery handbook, Fairmont Press, 1983.

4. R. Yadav, Steam & Gas Turbines and Power Plant Engineering, Central Publishing House, 7th Edition, 2000.

5. Goldstick, R. J. and Thumann, A: Principles of waste heat recovery, United States: N. p., 1985. Web.