NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF MECHANICAL ENGINEERING

Revised Curriculum and Syllabi

Program Name
Master of Technology in Fluid Mechanics and Heat Transfer
Effective from the Academic Year: 2021-2022

Recommended by DPAC	**: 03.08.2021**
Recommended in PGAC	**: 16.08.2021**
Approved by the Senate	**: 22.08.2021**

CURRICULUM

Sl. No.	Subject Code	Name of the Subject	L	T	S	C	H
Semester I							
1.	ME 1011	Advanced Fluid Mechanics	3	1	0	4	4
2.	ME 1012	Mathematical Methods in Engineering	3	1	0	4	4
3.	ME 1013	Convective Heat and Mass Transfer	3	1	0	4	4
4.	ME 90**	Specialization Elective - I	3	0	0	3	3
5.	ME 90**	Specialization Elective - II	3	0	0	3	3
6.	ME 1061	Thermo-Fluids Laboratory	0	0	4	2	4
7.	ME 1062	Numerical Simulation Laboratory	0	0	4	2	4
					Total Credit	**22**	**26**
Semester II							
1.	ME 2011	Microfluidics	3	1	0	4	4
2.	ME 2012	Computational Fluid Flow and Heat Transfer	3	1	0	4	4
3.	ME 2013 / ME 2014	Core- Elective	3	1	0	4	4
4.	ME 90**	Elective-III	3	0	0	3	3
5.	ME 90**	Elective-IV	3	0	0	3	3
6.	ME 2061	CFD Laboratory	0	0	4	2	4
7.	ME 2062	Mini Project with Seminar	0	0	6	3	6
					Total Credit	**23**	**28**
Semester III							
1.	XX90XX	AUDIT LECTURES / WORKSHOPS	0	0	0	0	2
2.	ME 3061	DISSERTATION - I	0	0	24	12	24
3.	ME 3062	SEMINAR - NON-PROJECT / EVALUATION OF SUMMER TRAINING	0	0	4	2	4
					Total Credit	**14**	**30**
Semester IV							
1.	ME 4061	DISSERTATION - II / INDUSTRIAL PROJECT	0	0	24	12	24
2.	ME 4062	PROJECT SEMINAR	0	0	4	2	4
					Total Credit	**14**	**28**
TOTAL CREDIT POINT: 73							

LIST OF ELECTIVE SUBJECTS

Sl. No.	Subject Code	Name of the Subject
1.	ME 9041	Experimental Methods in Thermal Science
2	ME 9042	Dynamical Systems
3	ME 9043	Fundamentals of Combustion
4	ME 9044	Fluid Power Systems and Control
5	ME 9045	Advanced Theory of Turbomachinery
6.	ME 9046	Lubrication Engineering
7.	ME 9047	Multi-Phase Flow and Heat Transfer
8.	ME 9048	Advanced Computational Fluid Dynamics
9.	ME 9049	Turbulence and Turbulent Flows
10.	ME 9050	Introduction to Aerodynamics
11	ME 9051	Microsystem Design
12	ME 9052	Gas Turbines and Jet Propulsion
13	ME 9053	Theory of Combustion
14	ME 9054	Renewable Energy Sources
15	ME 9055	Power Plant Engineering
16	ME 9056	Heat and Fluid Flow in Porous Media

LIST OF CORE- ELECTIVE SUBJECTS

SL NO	Subject Code	Name of the Subject
1.	ME2013	Conduction and Radiation Heat Transfer
2.	ME2014	Compressible Flow

Department of Mechanical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME1011	**Advanced Fluid Mechanics**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Fluid Mechanics, Engineering Mathematics in UG Programme		CT+EA					
Course Outcomes	• CO1: To introduce fundamental concept of fluid and its properties: concept of continuum • CO2: To introduce type of analysis of fluid motion • CO3: To learn fundamental equations of fluid flow • CO4: To learn analytical solutions of some steady and unsteady incompressible flows • CO5: To learn hydrodynamic stability • CO6: To learn concept of creeping flow and hydrodynamic lubrication. • CO7: To learn boundary layer concept • CO8: To learn concept of potential flow • CO9: To learn fundamental concept of turbulence and turbulent flow.						
Topics Covered	▪ Introduction, definition of fluids, concepts of stress, stress tensor, different approaches of describing fluid motions, Reynolds transport theorem and its application to conservation laws for control volume. (8) ▪ Kinematics of fluid motion, relative motion of fluid particles, Newton's law of viscosity, postulates of Stokes, relation between stress tensor to the rate of strain tensor (Stokesian fluid), Navier Stokes equation for constant-viscosity incompressible fluid, exact solution of Navier Stokes equation for several special cases. (12) ▪ Introduction to hydrodynamic stability, linear stability of plane Poiseuille flow, Orr-Sommerfeld equation, unsteady exact solution of Navier Stokes equation: Stokes first and second problem, hydrodynamic theory of lubrication, thin film equation, slider bearing. (10) ▪ Potential flow: Stokes' theorem, Laplace's equation, circulation, stram function and velocity potential, fundamental potential flows, combined flows, lift and drag for a cylinder with and without circulation. (8) ▪ High Reynolds number flow past a semi-infinite plate, and concept of boundary layer, Prandtl's boundary layer equation, approximate (von Karman momentum integral method) and exact solutions (Blasius solution) of the boundary layer equation for flat plate, boundary layer with pressure gradient,: Falkner-Skan flow past a wedge (10) ▪ Introduction to turbulence, Reynolds decomposition, Reynolds-averaged Navier Stokes equation, concept of turbulent stresses, Prandlt's mixing length hypothesis, near wall						

	velocity profile: law of the wall and velocity defect law, concept of eddy viscosity, turbulent intensity, turbulent kinetic energy. (8)
Text Books, and/or reference material	Text Books: 1. Title:Viscous Fluid Flow Author: White F.W. 2. Title: Boundary Layer Theory Author: Schlichting S. 3. Title:Viscous Flow Author: Sherman F. Reference Books 1. Title: Advanced Engineering Fluid Mechanics, Author: Muralidhar K.M., Biswas G. 2. Title:An Introduction to Fluid Dynamics, Author: Batchelor, G.K. 3. Title: Incompressible Flow: Panton, R. L.

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME1012	**Mathematical Methods in Engineering**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Engineering Mathematics in B. Tech Level		CT+EA					

Course Outcomes	CO1: To understand common numerical methods and how they are used to obtain approximate solutions. CO2: To derive numerical methods for various mathematical operations and tasks, such as interpolation, differentiation, integration, the solution of linear and nonlinear equations, and the solution of differential equations. CO3: To analyze and evaluate the accuracy of common numerical methods.	
Topics Covered	Topics	Hours
	Solution of linear simultaneous equations, matrix Inversion	6
	Solution of non-linear equation of one variable and solution of system of non-linear simultaneous equation	6
	Interpolation and curve fitting	4
	Numerical differentiation and integration	4
	Solution of ordinary differential equations and solution of partial differential equations	4
	Discrete and Fast Fourier transformation	5
	Analysis of Eigen value problems	4
	Application to different types of Boundary value, Initial value and Eigen value problems	4
	Brief discussion on software for numerical solution	2
Text Books, and/or reference material	**Text Books:** 1. Advanced Engineering Mathematics, E. Kreyszig 2. Numerical Methods for Scientist and Engineers, R. W. Hamming 3. Applied Mathematics for Engineers and Physicists By Pipes and Harvill	
	Reference Books: 1. Introduction to Numerical Analysis, F. B. Hildebrand 2. Fundamentals of Engineering Numerical analysis, P. Moin	

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME1013	**CONVECTIVE HEAT TRANSFER AND MASS TRANSFER**	PCR	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
MEC 304 (Engineering Thermodynamics) and MEC 403 (Heat and Mass Transfer)	CT+EA

Course Outcomes	• CO1: To understand the basic concepts and principles of Heat and Mass Transfer • CO2: To learn the basics of heat and mass transfer • CO3: To learn about forced and natural convections and heat transfer. • CO4: To Introduce physics of turbulent models.
Topics Covered	1. Governing Equations: Continuity, Momentum and Energy Equations and their derivations in different coordinate systems, Boundary layer Approximations to momentum and energy. (6) 2. Laminar External flow and heat transfer: (a) Similarity solutions for flat plate (Blasius solution), flows with pressure gradient (Falkner-Skan and Eckert solutions), and flow with transpiration, (b) Integral method solutions for flow over an isothermal flat plate, flat plate with constant heat flux and with varying surface temperature (Duhamel's method), flows with pressure gradient (von Karman-Pohlhausen method). (14) 3. Laminar internal flow and heat transfer: (a) Exact solutions to N-S equations for flow through channels and circular pipe, Fully developed forced convection in pipes with different wall boundary conditions, Forced convection in the thermal entrance region of ducts and channels (Graetz solution), heat transfer in the combined entrance region, (b) Integral method for internal flows with different wall boundary conditions. (10) 4. Natural Convection heat transfer: Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Similarity solutions for Laminar flow past a vertical plate with constant wall temperature and heat flux conditions, Integral method for natural convection flow past vertical plate, effects of inclination, Natural convection in enclosures, mixed convection heat transfer past vertical plate and in enclosures. Physical characteristics and dynamics of natural convection, Grashoff's number, modified momentum equation for natural convection boundary layer, natural convection around inclined and horizontal flat plate as well as inside enclosure (14) 5. Condensation and Boiling: physical characteristics and different modes of condensation, Nusselt's analysis for film wise condensation over a vertical flat plate, rate of condensation, average heat transfer coefficient and Nusselt number calculations, condensation around vertical and horizontal tube and array of tubes,Different modes of Boiling and Nukiyama's pool boiling curve, film boiling, forced convection boiling in tube (8) 6. Mass transfer. (4)

Text Books, and/or reference material	Text Books: 1. Convection Heat Transfer – A. Bejan 2. Title: Convective Heat Transfer Author: S. Kakac and Y. Yener 3. Convective Heat Transfer -- L.C. Burmeister 4. Principles of Convective Heat Transfer – M. Kaviany Reference Books: 1. Convective Heat and Mass Transfer – Kays and Crawford 2. Convective Heat and Mass Transfer – S. M. Ghiaasiaan 3. Heat Convection – L. M. Jiji 4. Title: Fundamentals of Heat and Mass Transfer, Author: F.P. Incropera and D. Dewitt 5. Title: Boundary Layer Theory, Author: H. Schlichting and K. Gersten

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
ME2011	**Microfluidics**	PCR	3	1	0	4	4

MEC303 Fluid Mechanics MEC304 Engineering Thermodynamics MEC403Heat Transfer and Mass Transfer PHC01 Engineering Physics CYC01 Engineering Chemistry BTC01 Life Science	Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))
NIL	CE+EA
Course Outcomes	• CO1: To learn micro channel flows with heat transfer. • CO2: To learn Surface Tension Driven Flows with real life applications. • CO3: To learn Electrohydrodynamics fundamentals • CO4: To learn Molecular Dynamics Simulations
Topics Covered	Lec-01 Introduction to Microfluidics: Origin, Definition, Benefits, Challenges, Commercial activities, Physics of miniaturization, Scaling laws, Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations -1hr. Lec-02 Microfluidics- Some Application Examples: Drug delivery, Diagnostics, Bio-sensing- 1hr. Lec-03 Equations of Conservation-1hr. Lec-04-05 Navier Stokes Equation-2 hr. Lec-07-08 Energy Equation-2 hr. Lec-09-13 Pressure –driven Microflows: Exact solutions, Couette flow, Poiseuille flow-5 hr. Lec-14-16 Some Examples of Unsteady Flows: Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel.- 3 hr. Lec-17-18 Stokes Drag on a Sphere: Stokes drag on a sphere, Time-dependent flows, Two-phase flows -2 hr. Lec-19-20 Lubrication Theory -2 hr. Lec-21-22 Boundary Condition in Fluid Mechanics - Slip or No-slip: Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects-2 hr.

	Lec-23-28 Surface Tension Driven Flows: Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect -6 hr. Lec-29-32 Thin Film Dynamics-4 hr. Lec-33-34 Lab on a CD-2 hr. Lec -35 Introduction to Microfabrication: Materials, Clean room, Silicon crystallography, Miller indices. Oxidation, photolithography- mask, spin coating, exposure and development, Etching, Bulk and Surface micromachining, Wafer bonding. Polymer microfabrication, PMMA/COC/PDMS substrates, micromolding, hot embossing, fluidic interconnections. -1 hr. Lec-36-41 Electrokinetics: Electrohydrodynamics fundamentals. Electro-osmosis, Debye layer, Thin EDL limit, Ideal electro-osmotic flow, Ideal EOF with back pressure, Cascade electro-osmotic micropump, EOF of power-law fluids. Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size. Dielectrophoresis, Induced polarization and DEP , Point dipole in a dielectric fluid, DEP force on a dielectric sphere, DEP particle trapping, AC DEP force on a dielectric sphere. Electro-capillary effects, Continuous electro-wetting, Direct electro-wetting, Electro-wetting on dielectric-7 hr. Lec-42 Dispersion-1 hr. Lec-43-44 Introduction to Nanofluidics-2 hr. Lec-45 Introduction to Molecular Dynamics Simulations-1 hr. Lec-46-47 Bio microfluidics -2 hr. Lec-48 Nanofluidic Energy Conversion-1 hr.
Text Books, and/or reference material	Suggested Text Books: 1) Microfluidics - Stéphane Colin 2) Micro- and Nanoscale Fluid Mechanics, Transport in Microfluidic Devices- Brian Kirby, Cambridge University Press . Suggested Reference Books: 1) Theoretical Microfluidics-Henrik Bruus, Oxford University Press. 2) Fundamentals and Applications of Microfluidics: Nam- Trung Nguyen and Steven T. Wereley 3) Advanced Transport Phenomena: Fluid Mechanics and Convective Transport - L. Gary Leal

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME2012	**COMPUTATIONAL FLUID FLOW & HEAT TRANSFER**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Fluid Mechanics, Convective Heat and Mass Transfer, Conduction and Radiation, Mathematical Methods in Engineering		CT+EA					
Course Outcomes	• CO1: To introduce the physical and computational aspects of the governing equations of transport processes						

	• CO2: To introduce numerical techniques in fluid flow and heat transfer problems • CO3: To introduce the stability of different numerical schemes • CO4: To learn different discretization methods of computational fluid dynamics • CO5: To learn application of numerical techniques in solving engineering transport processes
Topics Covered	**Module I:** Introduction to computational fluid dynamics and principles of conservation: continuity equation, Navier-Stokes equation, energy equation and general structure of conservation equations, classification of partial differential equations and physical behaviour (10) **Module II:** Approximate solutions of differential equations: error minimization principles, variational principles and weighted residual approach, fundamentals of discretization: finite difference, finite volume and finite element methods, grid generation techniques (10) **Module III:** Boundary condition implementation and discretization of unsteady state problems, important consequences of discretization of time dependent diffusion type problems and stability analysis : consistency, stability and convergence, lax equivalence theorem, grid independent and time independent study, stability analysis of parabolic equations (1-D unsteady state diffusion problems): FTCS (forward time central space) scheme, stability analysis of parabolic equations (1-D unsteady state diffusion problems): CTCS scheme (leap frog scheme), Dufort-Frankel scheme, stability analysis of hyperbolic equations: FTCS, FTFS, FTBS and CTCS schemes, finite difference discretization of 2-D unsteady state diffusion type problems, solution techniques for systems of linear algebraic equations, discretization of convection-diffusion equations, discretization of Navier-Stokes equations: stream function vorticity approach and primitive variable approach: fractional-step method (projection method), simplified MAC (SMAC) method (22) **Module IV:** Introduction to finite volume method (FVM) of discretization: Conservative differential form and integral form governing equations of fluid flow, finite volume method for 2-D unsteady state diffusion problems, finite volume method for convection-diffusion problems, solution algorithm for pressure-velocity coupling in steady flows: SIMPLE, SIMPLER and PISO algorithms (14)
Text Books, and/or reference material	Text Books: 1. Computational Fluid Mechanics and Heat Transfer –Anderson, Tannehill, and Pletcher 2. Computational Methods for Fluid Dynamics –Ferziger and Peric 3. Computational Techniques For Fluid Dynamics – Fletcher 4. Fundamentals of Computational Fluid Dynamics – Roache 5. Computational Fluid Dynamics and Heat Transfer – Ghoshdastidar Reference Books: 1. An Introduction to Computational Fluid Dynamics: The Finite Volume Method – Versteeg and Malalasekera 2. Numerical Heat transfer and Fluid flow – Patankar

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<tr><th colspan="9">Department of Mechanical Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>ME2013</td><td>CONDUCTION AND RADIATION HEAT TRANSFER</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">MEC 305 (fluid Mechanics), MEC 304 (Engineering Thermodynamics) and MEC 403 (Heat and Mass Transfer)</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">● CO1: To acquire an idea about conduction transport mechanism
● CO2: To learn the basics of heat and mass transfer
● CO3: To learn the basic knowledge of Black body radiation.
● CO4: To learn the basic concept of Radiation heat exchange between real surfaces.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">1Conduction: Steady and unsteady problems and their solutions in Cartesian, cylindrical and spherical coordinates. (6)

2One dimensional steady state situation, concept of thermal resistance, critical radius of insulation. Differential equation of heat conduction. Heat generation. Unsteady state heat conduction. Separation of variables. Duhamel’s theorem. Laplace transform. Problems involving change of phase. Inverse heat conduction, Micro scale heat transfer. (10)

3. Fins problems, pin fin, temperature distribution of pin fin. The effectiveness of pin fin. (4)

4. Numerical solution of conduction problems: Basic ideas of finite difference method – forward, backward and central differences – Discretization for the unsteady heat equation – simple problems. Basis ideas of the finite volume method – application to Laplace and Poisson equations. (8)

5. Properties of Surfaces: Introduction, Black Body Radiation, Radiative properties of real surfaces. (10)
6. Radiation Exchange between surfaces: Introduction, Shape factor, Evaluation of shape factors, Radiation exchange between Gray surfaces enclosure (12)
7. Gas Radiation: Introduction, Beer's law, Emissivity and Absorptivity of gases and gas mixtures, Radiation and climate. (6)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Title: Conduction and Radiation Author: K. Muralidhar,
2. Title: Heat Conduction Author: SadikKakac and YamanYener
3. Thermal Radiation Heat Transfer - Sigel R and Howell J
4. Radiative Heat Transfer - Michael F Modest
Reference Books:
1. Title: Heat Conduction Author: Hahn, D. W. and Ozisik M. N.,</td></tr>
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Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME2014	**Compressible Flow**	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Fluid Mechanics and Thermodynamics studied in B.Tech/BE Course		CT+EA					
Course Outcomes	• CO1: To learn compressible flows with constant entropy only, with friction only and with heat transfer only. • CO2: To learn Normal shock, oblique Shock and Prandtl-Meyer Flow with real life applications. • CO3: To learn how to design the supersonic aerofoils.						
Topics Covered	• 1-D gas dynamics: Basic governing equations, Flow with Variable area duct without normal shock and with normal shock. Fanno flow and Rayleigh flow. Solution of problems using gas table. 16 • 1-D wave motion: wave propagation – simple and finite waves, 2-D waves, governing equations. Moving Normal shocks and oblique shocks: Normal velocity superposition for moving Normal shock and tangential velocity superposition for oblique shock, oblique shock analysis for perfect gas, oblique shock table and charts.Prandtl-Meyer flow: Isentropic turn (either around expansion or compression corner) from infinitesimal shocks, Mach waves, Prandtl-Meyer flow analysis, Prandtl-Meyer function, overexpanded and underexpanded nozzles, boundary conditions for flow direction and pressure, shock diamond, supersonic aerofoils, Working of supersonic wind tunnel. **24 hrs** • Correlation of Fanno flow, Rayleigh flow, and a normal shock Linearized flow: subsonic flow–Goethert's and Prandtl-Glauert rules, hodograph methods, supersonic thin airfoils, supersonic 2-D airfoils, application of oblique shock and Prandtl-Meyer to calculate Lift and Drag on supersonic aerofoils, 16						
Text Books, and/or reference material	Text Books: 1. Fundamentals of gas dynamics -R.D. Zucker & Oscar Biblarz. Reference Books: 1. The Dynamics and Thermodynamics of Compressible Fluid Flow- A. H. Shapiro.						

SESSIONAL/LAB

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<tr><td colspan="9">Department of Mechanical Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>ME 1061</td><td>Thermo-Fluids Laboratory</td><td>PCR</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5"></td></tr>
<tr><td colspan="3">Fluid Mechanics, Convective Heat and Mass Transfer, Conduction and Radiation</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">● CO1: To learn the fundamentals of experimental techniques
● CO3: To perform experimental validation of theory in Fluid Mechanics and Heat Transfer
● CO2: To learn the design and analysis of experiments</td></tr>
<tr><td>Topics Covered</td><td colspan="7">1. To measure the wall static pressure and pressure distribution at different sections of a straight duct and curved duct for incompressible flow of air. (4)
2. To measure the wall static pressure and pressure distribution at different sections of a straight diffuser for incompressible flow of air. (4)
3. To determine the thermal conductivity of brass using linear and radial conduction apparatus. (4)
4. To determination of convective heat transfer coefficient and actual mass flow rate of air for forced flow of air through unknown specimen under variable condition.(4)
5. To measure the boundary layer thickness at various locations on a flat plate for different Reynolds numbers with incompressible flow of air. (4)
6. To study of Heat Transfer Enhancement with the Application of Nanofluids in a Differentially Heated Cavity. (4)
7. To determine the average heat transfer coefficient of single and multiple microchannels heat sink.
8. To determine the microchannel's heat transfer coefficient and pressure drop with the different hydraulic diameter, aspect ratio, and channel numbers of micro sink.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Springer Handbook of Experimental Fluid Mechanics—Tropea and Yarin
2. Instrumentation, Measurements, and Experiments in Fluids---Rathakrishnan
3. Thermal and Flow Measurements---T.-W. Lee
Reference Books:
1. Experimental Methods for Engineers---Holman</td></tr>
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Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 1062	**Numerical Simulation Laboratory**	PCR	0	0	4	4	2
Pre-requisites							
Basic knowledge in Numerical Methods		CT+EA					
Course Outcomes	• CO1: To write different numerical methods related to engineering problems. • CO2: To writing Computer programming to solve various engineering problems by numerical methods.						
Topics Covered	1. Programming using high level language (C/C++/Fortran/MATLAB) (8) 2. Computer programming for solving linear simultaneous equations, non-linear equations.(8) 3. Numerical differentiation and integration.(8) 4. Solution of ordinary differential equations and solution of partial differential equations.(8) 5. Eigen value problems, Boundary value, Initial value problems.(4) 6. Problems as assigned by the respective teachers.(4)						
Text Books, and/or reference material	Text Books: 1. Numerical Methods By B. S. Grewal 2. Applied Numerical Methods for Digital Computation By M. L. James, G. M. Smith and J. C. Wolford 3. Numerical Methods for Engineers By S.C. Chapra and R. P. Canale Reference Books 1. Numerical Methods for Engineers By D. V. Griffiths and I. M. Smith 2. Numerical Recipes By W. H. Press, S. A. Teukolsky, W. T. Vetterling and B. P. Flannery. 3. Computer aided Mechanical Design and Analysis By V. Ramamurti						

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 2061	**CFD Laboratory**	PCR	0	0	4	4	2
Pre-requisites							
Basic knowledge in fluid dynamics, heat transfer and numerical methods		CT+EA					
Course Outcomes	• CO1: To writing computer programming in finite difference method (FDM) using high level language • CO2: To Learn the use of commercially available CFD software to solve some basic fluid dynamics and heat transfer problems						

Topics Covered	**Part I: Code development in finite difference/ finite volume methods using Matlab/C++ as interface(20)** ▪ 1-D steady heat conduction problem (determine the temperature distribution along the axis of a fin) ▪ 2-D steady heat conduction problem (determine the temperature distribution on a rectangular slab) ▪ 1-D/2-D unsteady heat conduction problem (determine the transient temperature distribution along the axis of a fin/on a rectangular slab) ▪ Lid-driven cavity flow using stream-function vorticity technique **Part II: Developing Solution of CFD problems using ANSYS-FLUENT/ COMSOL Software (20)** ▪ Axisymmetric flow through a circular pipe under isothermal condition ▪ Axisymmetric flow through a circular pipe under non-isothermal condition ▪ Blasius flow over a flat plate ▪ Flow past a solid, circular cylinder (Re: 30-70) ▪ Natural convection along a vertical flat plate
Text Books, and/or reference material	Text Books: 1. Numerical heat transfer and fluid flow. CRC press. By Patankar, S. 2. Computational fluid dynamics: the finite volume method. Harlow, England: Longman Scientific & Technical. By Versteeg, H. K., and W. Malalasekera. 3. ANSYS fluent theory guide 15.0. Reference Books 1. Computational fluid dynamics. New York: McGraw-Hill. By Anderson, J. D. 2. Computational methods for fluid dynamics. Springer Science & Business Media. By Ferziger, J. H. and Peric, M.

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Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 2062	**Mini Project with Seminar**	PCR	**0**	**0**	**0**	**6**	**3**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NA		CT+EA					
Course Outcomes	CO1: To be able to conduct review of literature to arrive at selected advanced topic for project work. CO2: Ability to interpret ideas and thoughts into practice in a project. CO3: Ability to analyze the gap between theoretical and practical knowledge. CO4: To be able to write and present a technical report with suitable conclusion as per international standards CO5: To be able to discuss and depend the outcome of the report in a seminar						
Topics Covered	Project as decided based on literature survey with consultation with the supervisor						

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 3061	**DISSERTATION - I**	PCR	**0**	**0**	**24**	**24**	**10**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1: Ability to interpret ideas and thoughts into practice in a project. CO2: Ability to analyze the gap between theoretical and practical knowledge. CO3: Ability to compose technical presentation in the conferences. CO4: Ability to prepare for publishing papers in journals. CO5: Ability to propose for the patent rights for the projects.						
Topics Covered	Project as decided based on literature survey with consultation with the supervisor						

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 3062	**Seminar (Non Project)**	PCR	**0**	**0**	**4**	**4**	**2**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1: To be able to conduct review of literature to arrive at selected advanced topic for seminar. CO2: To be able to summaries the concept of the chosen topic systematically after considerable study of the content from primary as well as secondary sources CO3: To be able to write and present a technical report with suitable conclusion as per international standards CO4: To be able to discuss and depend the outcome of the report in a seminar						
Topics Covered	Topics decided by consultation with the supervisor						

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 4061	**DISSERTATION - II / INDUSTRIAL PROJECT**	PCR	**0**	**0**	**24**	**24**	**14**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1: Ability to interpret ideas and thoughts into practice in a project. CO2: Ability to analyze the gap between theoretical and practical knowledge. CO3: Ability to compose technical presentation in the conferences. CO4: Ability to prepare for publishing papers in journals. CO5: Ability to propose for the patent rights for the projects.						
Topics Covered	Project as decided based on literature survey with consultation with the supervisor						

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 4062	**Project Seminar**	**PCR**	**0**	**0**	**4**	**4**	**2**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1: Ability to assess knowledge in the subject and the project. CO2: Ability to integrate technical question through all the years of study. CO3: Ability to express and communicate.						

Specialization Elective Subjects

<table>
<tr><td colspan="9">Department of Mechanical Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>ME9041</td><td>Experimental Methods in Thermal Science</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Fluid Mechanics, Thermodynamics and Heat Transfer in B.Tech/BE Course</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To acquire an idea about basic concepts of measurements
CO2: To learn the basics of data acquisition and data analysis
CO3: To learn the measurement techniques for pressure, temperature, flow, velocity etc.
CO4: To learn the fundamentals of wind tunnel measurements.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Basic concepts: Calibration, Standards, Dynamic measurement, System response and Fourier analysis, Distortion, Experiment planning (6)
Data analysis: Error analysis, Uncertainty analysis, Statistical analysis, Graphical analysis and curve fitting, Multivariable regression, Goodness of fit (7)
Flow measurement and Flow-Visualization methods (5)
Measurements of thermo-fluid-dynamic variables: pressure, temperature, velocity, etc. (6)
Measurements of thermal-and-transport-property: viscosity, thermal conductivity, diffusion coefficient, pH, humidity, etc. (4)
Calorimetry (1)
Convection heat-transfer measurements and various heat-flux meters (2)
Measurement of thermal radiation, emissivity, reflectivity and transmissivity, Measurements of solar radiation, Detection of nuclear radiation (5)
Wind tunnel: introduction, instrumentation and calibration of wind tunnels (4)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Experimental Methods for Engineers – J. P. Holman
2. Instrumentation, measurements and experiments in Fluids by E. Rathakrishnan

Reference Books:
1. Handbook of experimental fluid mechanics, Tropea et al.
2. Measurement systems—application and design, Doebelin, E. O.
3. Handbook of heat transfer, Rohsenow et al.</td></tr>
</table>

Department of Mechanical Engineering

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME9042	**Dynamical systems**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Basics of all Engineering, Mathematics, Physics, Chemistry, and Biology	CT+EA

Course Outcomes	• CO1: To learn stability analysis of nonlinear transient problems in all fields. • CO2: To learn Chaos of nonlinear transient problems using dynamical behaviors (Bifurcations, FFT, Poincare Maps, Lyapunav exponents, Henon maps and Fractals)
Topics Covered	One- Dimensional Flow: Flows on the line, fixed points and stability, linear stability, real life problem and exercises; Flows on circle, Fixed points and stability, real life problem and exercises; Bifurcations: Types of bifurcations, Normal forms of saddle-node , transcritical, pitchfork, Supercritical and Subcritical bifurcations,and imperfect berfercations real life problem and exercises 13 Two -Dimensional Flows: Linear system, Definitions and examples, Classification of Linear system, Exercises, Phase plane, Phase portraits, Fixed points and Linearization of nonlinear systems, Exercises, Limit cycles, Definition and understanding with examples, Poincare theory, FFT of time series data, Exercises, Bifurcations of 2-D system, Saddle-node, Transcritical and Pitchfork Bifurcations, Hopf Bifurcations and its type with normal form, Hopf point and fold points, Hysteresis zone, Poincare map, FFT and phase portrait, Exercises 22 Chaos: Lorenz Equations, Properties of Lorenz Equations, Lorenz map, Exploring parameter Space, Exercises, One-Dimensional Maps, Fixed points and Cobwebs, Logistic maps, Lyapunov Exponent, Exercises, Fractals, Countable and uncountable sets, Cantor Sets, Dimension of a self similar Fractals, Box dimension, Point wise Correlation Dimensions, Exercises, Strange attractor, Simplest examples, Henon map, Physical examples, Exercises. 21
Text Books, and/or reference material	Text Books: 1. Nonlinear dynamics and Chaos by S. H. Strogatz Reference Books: 1. Chaos and nonlinear dynamics by R. C. Hilborn 2. Differential dynamical systems by J. D. Meiss

Text Books:
1. Nonlinear dynamics and Chaos by S. H. Strogat Reference

Books
1. Chaos and nonlinear dynamics by R. C.Hilborn
2. Differential dynamical systems by J. D.Meiss

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
ME9043	**Fundamentals of Combustion**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))
MEC304 (Engineering Thermodynamics) MEC303 (Fluid Mechanics) MEC403 (Heat and Mass Transfer)	CE+EA

Course Outcomes	• CO1: To understand the physical process involved in combustion • CO2: To be able to model a process involving combustion. • CO3: To acquire an in-depth idea about laminar flames. • CO4: To understand partially premixed flames. • CO5: To learn the intricacies of turbulent flames.
Topics Covered	• Review of thermodynamics, Chemical kinetics, Mass transfer definitions: Fick's law (7) • Equations of conservation of species mass, momentum, and energy; multi-component diffusion equation (5) • Schvab-Zel'dovich formulation, Rankine-Hugoniot relations. (5) • Laminar premixed flames: Flame speed, flammability limits, flame stabilization, ignition and quenching. (7) • Laminar diffusion flames: Burke-Schumann problem and droplet burning. (5) • Partially premixed flames (7) • Turbulent flames (6)
Text Books, and/or reference material	<u>Suggested Text Books:</u> 3) Principles of Combustion – K. K. Kuo 4) An introduction to combustion – S. R. Turns Suggested Reference Books: 4) Combustion physics – C. K. Law

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME9044	**Fluid Power Systems and Control**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Fluid Mechanics, Control Engineering		CT+EA					
Course Outcomes	• CO1: To build up concept of hydraulic and pneumatic power system and their application areas. • CO2: To familiarise the students about functioning of several components of hydraulic power system and techniques for dynamic analysis of those components. • CO3: To make them able to design hydraulic power pack using several components for particular application according to specific requirements. • CO4: To make them understood the procedures to control the overall hydraulic power system and troubleshoot the problems arising out.						
Topics Covered	**Introduction**: introduction, concept of hydraulic and pneumatic power system and their application, advantages and disadvantages; basic hydraulic and pneumatic circuit, fluid flow fundamentals, flow through orifice and conduit, minor losses.. (5) **Hydraulic Fluid**: density, viscosity, effective bulk modulus; thermal properties and equation of state; chemical properties-contamination and filtration; types of hydraulic fluid, selection of hydraulic fluid (3) **Hydraulic Pump, Motor and Actuator**: types and construction of basic hydraulic pumps and motor; rotary and linear actuators-types and construction, dynamics of hydraulic pumps and motor. (6) **Control Valves**: types of valves and their configurations and symbols, spool valves, poppet valve, flapper nozzle valve, functioning of pressure relief and pressure reducing valves, direction control valves and pressure compensated flow control valves and their dynamic analysis (10) **Fluid Power System and Dynamics**: basic fluid power systems; dynamics of valves, valve flow characteristics, flow force and spool stiction, friction in valve and actuators, leakage flow through valve and actuator ; transmission line dynamics, actuator dynamics, hydraulic accumulator. (14) **Electro-hydraulic Servo System**: types of EHSVs, permanent magnet torque motor, two stage flapper nozzle EHSV dynamics with feedback control, design and control of elctro-hydraulic servo mechanism, stability and frequency response analysis (10)						
Text Books, and/or reference material	Text Books: 1. Hydraulic Control System by Merritt H, John Wilely and Sons Inc. 2. Fundamentals of Fluid Power Control by Watton J. Cambridge University Press. 3. Fluid Power Engineering by M G Rabie, McGraw Hill Reference Books 1. Fluid Power Systems: modeling, simulation and microcomputer control by John Watton, Prentice Hall International. 2. Fluid Power Control by Blackburn, J. F., G. Reethof, and J. L. Shearer, New York: Technology Press of M. I. T. and Wiley.						

<table>
<tr><th colspan="9">Department of Mechanical Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>ME9045</td><td>ADVANCED THEORY OF TURBOMACHINERY</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Engineering Thermodynamics, Heat and Mass Transfer, Fluid Mechanics in UG Programme</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">Acquire knowledge about rotodynamic machines for producing or using power:
• <u>CO1</u> Details of axial and radial flow gas/steam and hydraulic turbines used for generating electric power
• <u>CO2</u> Recap of details of hydraulic pumps as rotodynamic machine
• <u>CO3</u> Details of axial flow and centrifugal compressor (in comparison with fans and blowers) with its importance in aviation industry</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction: Basic Principles:
Definition of a turbo machine, The fundamental laws, The equation of continuity, The first law of thermodynamics, The momentum equation, The second law of thermodynamics – entropy, The thermodynamic properties of fluids, compressible flow relations for perfect gases.
Exercise Problems. 4 hours

Dimensional Analysis: Similitude
Dimensionality, Similitude, Dimensionless Performance variables and similarity for turbo machinery, Compressible flow similarity, Specific speed and specific diameter.
Exercise Problems. 4 hours

Two Dimensional Cascades:
Introduction, Cascade geometry, Velocity triangles, Mean velocity and mean flow direction, Blade inlet angle, Blade exit angle, Inlet flow angle, Exit flow angle, Incidence, Deviation, Camber angle, Deflection, Nominal incidence, Nominal deviation, ,Nominal deflection, Space-chord ratio. 4 hours
Analysis of cascade forces, Lift and drag forces, Lift and drag co-efficient
4 hours
Incompressible cascade analysis, Lieblein diffusion factor, Pressure rise co-efficient, Diffuser efficiency of the cascade and total pressure loss co-efficient and their relation, static pressure rise, blade load ratio.
Exercise Problems. 2 hours

Axial Flow Turbines:
Introduction, Velocity diagrams of the axial turbine stage, Turbine stage design parameters, Flow coefficient, Stage loading factor, Stage reaction, Expressions for the reaction in terms of the flow angles, Velocity triangles and Mollier diagrams for R= 0,0.5,1.0, Thermodynamics of the axial turbine stage.
4 hours
Repeating stage turbine, Stage losses and efficiency, Total-to-total efficiency of a turbine stage, Total-to-static efficiency, Enthalpy loss co-efficient for stator and rotor.
Exercise Problems. 6 hours</td></tr>
</table>

	Radial Flow Turbines: Introduction, types, IFR tubines, kinematic and thermodynamic analysis of turbine stage, turbine stage design parameters, nominal design point efficiency, Mach number relations, loss coefficient, number of blades, rotor exit consideration. 9 hours Axial flow compressors: Introduction, 2-D analysis of compressor stage, kinematic and thermodynamic analysis of compressor stage, stage loss relationship and efficiency, reaction ratio and choice of reaction, stage loading, stage pressure rise, pressure ratio of a multistage unit, stage efficiency, stall and surge phenomena. 8 hours Centrifugal compressors: Introduction, kinematic and thermodynamic analysis of compressor stage, inlet casing, impeller, diffuser, conservation of rothalpy, optimum efficiency at inlet of pump/compressorslip factor, compressor performance, choking in compressor stage. 8 hours Introduction to 3-D flow in axial turbomachines. 3 hours
Text Books, and/or reference material	Text Books: 1. Title: Fluid Mechanics and Thermodynamics of Turbomachinery, Author: Dixon and Hall 2. Title: Fluid Mechinery, Author: Wright and Gerhart Reference Books: 1. Title: Turbomachinery: Basic Theory and Applications, Author: Earl Logan, Jr 2. Title: Gas Turbine Theory, Author: Saravanamutto, Cohen, and Rogers. 1. Convection

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME9046	**LUBRICATION ENGINEERING**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
1. Mechanics, Solid Mechanics, Fluid Mechanics		CT+EA					

Course Outcomes	• CO1: To learn the basic knowledge of surface topography and contact between engineering surfaces. • CO2: To learn the basic theory and application of friction and wear for different materials • CO3: To learn about lubricants and lubrication for different bearings • CO4: Introduced to Biotribology of human joints • CO5: Introduced to Microtribology for MEMS applications
Topics Covered	• **Surface topography:** Measurement of surface topography; Quantifying surface roughness; The topography of engineering surfaces. (3)

	• **Contact between surfaces:** Hertzian contact – sphere on sphere contact and cylinder on cylinder contact; Contact between rough surfaces. (5) • **Friction and Wear of contact surfaces:** Laws and Theories of friction and wear; Friction and Wear of different materials; Application to friction materials. (10) • **Lubricants and lubrication:** Viscosity of lubricants; Composition and properties of oils and greases; Reynolds equation; Type of lubrications - Hydrostatic lubrication, Hydrodynamic lubrication; Elastohydrodynamic lubrication; Boundary lubrication, and application to bearings. (20) • **Microtribology:** Surface forces and adhesion; Atomic force microscopy (AFM); Friction, wear and lubrication on atomic level; Applications to MEMS. (8) • **Biotribology:** Natural human joints; Structure and properties of articular cartilage; Mechanism of synovial lubrication: Mechanism of articular cartilage damage; Artificial joint replacements; Skin Tribology (10)
Text Books, and/or reference material	Text Books: 1) Engineering Tribology - Dr. Prasanta Sahoo 2) Introduction to Tribology of Bearings -- B.C.Majumder 3) Principles of Tribology-- J.Halling 4) Basic Lubrication Theory - Alastair Cameron

Department of Mechanical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME9047	**Multi-Phase Flow and Heat Transfer**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
		CT+EA					

Course Outcomes	• Leads students toward a clear understanding and firm grasp of the basic principles of multi phase flow and heat transfer. • Understands the fluid-dynamic involved in convection and multi-phase heat transfer. • Performs elementary analysis of most gas-liquid two-phase systems and prepares to use more advanced models. • Equips the student with the analytical model to apply the fundamentals to a wide variety of complex engineering problems, formulate them and interpret the results. • Student can analyze Hydrodynamics of three phase flows and compare two phase flow situations.
Topics Covered	Introduction, Flow Regimes, (5) Homogeneous Flow, Separated Flow (4) Condensation, (2)

	One dimensional steady separated flow model, (6) Flow in which inertia effects dominate, energy equations, (3) The separated flow model for stratified and annular flow, (2) General theory of drift flux model, (3) Application of drift flux model to bubbly and slug flow, (4) Hydrodynamics of solid-liquid and gas-solid flow, (4) An introduction to three phase flow, (3) Fluid-Population Balance Technique, Volume of Fluid Method, Lattice Boltzmann Model. (6)
Text Books, and/or reference material	Ghiaasiaan, S. M., Two-Phase flow, Boiling, and Condensation, Cambridge University Press. Brennen, C.E., Fundamentals of Multiphase Flow, Cambridge University Press Collier, J. G. and Thome, J. R., Convective Boiling and Condensation, 3rd ed., Oxford University Press Wallis, G.B., One Dimensional Two Phase Flow, McGraw Hill Higher Education. Hewitt, G.F., Measurement of Two Phase Flow Parameters. Govier, G.W., and Aziz, k., Flow of Complex Mixtures. Hetsroni, G., Handbook of Multiphase systems.

Subject Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
ME 9048	**Advanced Computational Fluid Dynamics**	PEL	3	0	0	3	3

Discretization procedure in finite volume method for diffusion problems: Finite volume method for 1-D steady state diffusion, 2-D and 3-D steady state diffusion, Example problems. Finite volume method for convection-diffusion problems: Steady 1-D and 2-Dconvection-diffusion, Conservativeness, Boundedness and Transportiveness, Central, Upwind, Hybrid and Power law schemes, QUICK and TVD schemes [10]

Pressure - velocity coupling in steady flows: Staggered grid, SIMPLE algorithm, Assembly of a complete method, SIMPLER, SIMPLEC andPISOalgorithms [8]

Finite volume method for unsteady flows: 1-D unsteady heat conduction, explicit, Crank-Nicolson and fully implicit schemes, Transient problems with QUICK, SIMPLE schemes. Implementation of boundary conditions: Inlet, Outlet, and Wall boundary conditions, Pressure boundary condition, Cyclic or Symmetric boundarycondition. [8]

Computation of turbulent fluid flow and heat transfer, eddy-viscosity based turbulence modelling : k-ε and k-ω modelling, Conjugate heattransferproblem [10]

Errors and uncertainty in CFD modeling: Errors and uncertainty in CFD, Numerical errors, Input uncertainty, Physical model uncertainty, Verification and validation, Guide lines for best practices in CFD, Reporting and documentation ofCFDresults. [4]

Text Books:
1. Title: A First Course in Turbulence Author: Tennekes, H. and Lumley,J.
2. Title: Turbulent Flows Author: Pope, S. B.

ReferenceBooks
1. Title: Turbulence: An Introduction for Scientists and Engineers, Author: P.A.Davidson
2. Turbulent Flows, Authors: Biswas, G. and Easwaran,V.

Subject Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
ME 9049	**Turbulence and Turbulent Flows**	PEL	3	0	0	3	3

Origin, examples & character of turbulence, Reynolds stress, energy relations, closure problem, phenomenology, eddy viscosity. Statistics. Spectra, space-time correlations, macro & micro scales, stat. theory of turbulence, locally isotropic turbulence, Kolmogorov's hypothesis, correlation method, spectral method, turbulent diffusion.Experimentaltechniques. [20]
Types of turbulent flows. Uniform turbulent flows under axial press gradient. Incompressible free turbulent flows: 2-D and axi-symmetric jets; wakes; free shear layer, self-propelled wake, and thermal plume.
Incompressible wall turbulent flows: pipe, channel flow, equilibrium turbulent & compressible BL, wall jet, turbulent transport in homogeneous & shear flow, compressible flows, Turbulence modelling. [20].

Text Books:
1. Title: A First Course in Turbulence Author: Tennekes, H. and Lumley,J.
2. Title: Turbulent Flows Author: Pope, S. B.
ReferenceBooks
1. Title: Turbulence: An Introduction for Scientists and Engineers, Author: P.A.Davidson
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Department of Mechanical Engineering

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
ME9050	**Introduction to Aerodynamics**	PEL	3	0	0	3	3

Pre-requisites	**Course Assessment methods**: Continuous evaluation (CE),Mid Term Exam(MTE) and End Assessment (EA)
Engineering Mechanics, Fluid Mechanics	CE(15)+MTE (25)+EA(60)

Course Outcomes	
	• CO1: To **understand** the basic conservation equations • CO2: To **apply** the concept to aerodynamical analysis • CO3: **To analyse** the flow field around the airplane during it's motion
CO1	Equations of Fluid Motion - Navier - Stokes Equation, Conservation of Energy and Energy Equation, Equations of Motions, Exact Solution for Simple Problems**6**
CO2	Aircraft and Aerodynamic Forces and Moments, Fluids and Forces in Fluids, Kinematics of fluid motion - Velocity with specified extension and vorticity, Vorticity Distribution, Velocity without expansion and vorticity, Irrotational Solenoidal Flow in Multiply Connected region. **10** Vortex motion : Helmholtz laws and Kelvin's theorem, Point vortex, vortexsheet, Biot-Savart law. Incompressible flow past airfoils. Airfoil nomenclature and characteristics. Kutta condition, starting vortex. Method of singularities and thin airfoil theory. **12** High Reynolds Number Approximation, Conditions for Incompressibility, Potential Flow - Combination of Basic Solutions – Lifting Cylinder, Conformal Transformation, Zhukovsky Transformation, Zhukovsky Transformation – Applications, Transformation, Boundary - Layer Theory **10** Incompressible flow past finite wings. Wing nomenclature. Prandtl's lifting line theory.

CO3	Induced drag. Effect of geometrical parameter on lift and induced drag. Element of lifting surface theory. Flow past swept and delta wings. Elements of flow past bodies in incompressible flow. Lift, drag and moment characteristics of the entire airplane. **14**
Text Books, and/or reference material	Suggested Text Books: 1) Fundamentals of Aerodynamics by John D. Anderson JR. Suggested Reference Books: 1) Introduction to Theoretical Aerodynamics and Hydrodynamics By William R. Sears

Department of MechanicalEngineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutoria l (T)	Practical (P)	Total Hours	
ME 9051	**Microsystem Design**	PEL	**3**		**0**	**3**	**3**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Solid Mechanics, Fluid Mechanics, Machine Design		CT+EA					

Course Outcomes	CO1: Able to understand scope and application of Microsystems CO2: Able to learn science behind micro system design. CO3: Students will be able to analyze micro system by computer aided tools CO4: Able to understand the different manufacturing technologies for micro system.	
Topics Covered		Hours
	Introduction: Overview of Microsystems and MEMS, Scaling laws in miniaturization, Application of micro systems	2
	Working Principles of Microsystems: Microsensors like Piezoresistive pressure sensors, micro-accelerometer, optical sensors etc., microactuators, micro pumps, micro valves, micro gears etc.	7
	Engineering Science for Microsystem Design and Manufacturing: Scaling effect in geometry, molecular theory of matter and intermolecular forces.	4
	Electrokinetics: Electrohydrodynamics fundamentals. Electro-osmosis, Debye layer, Thin EDL limit, Ideal electro-osmotic flow, Ideal EOF with back pressure, Cascade electro-osmotic micropump, EOF of power-law fluids. Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size.	4
	Dielectrophoresis, Induced polarization and DEP , Point dipole in a dielectric fluid, DEP force on a dielectric sphere, DEP particle trapping, AC DEP force on a dielectric sphere. Electro-capillary effects, Continuous electro-wetting, Direct electro-wetting, Electro-wetting on dielectric.	5
	Thermo-fluid Analysis for Microsystem Design: Scaling effect in fluid flow and heat transfer, fluid flow in submicrometer scale, microfluidics systems, heat conduction in solids in submicron level.	4
	Modeling of Coupled Electromechanical Systems: Scaling effect in electrostatic and electromagnetic forces, coupled electromechanics of static and dynamic microsystems	4
	Material for Microsystems and MEMS	2
	Modern Computational Tools for Microsystems Design and Analysis:	2

	Microsystem Fabrication Technologies: Thin film deposition, Lithography, etching, LIGA, silicon micromachining, inkjet printing etc.	6
	Microsystem Packaging:	2
Text Books, and/or reference material	**Text Books:** Text Books: 1. Microsystem Design by Stephen DSenturia 2. Micro and Smart Systems, by Ananthasuresh, Vinoy, Gopalakrishnan, Bhat,Aatre 3. MEMS and Microsystems Design & Manufacture, by Tai RanHsu Introduction to Micromechanisms and microactuators, by A.Ghosh, B.Corves	
	Reference Books: 1. An Introduction to MEMS Engineering, by Nadim andWilliams Foundation of MEMS, by ChangLiu	

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)$^{\#}$	Total Hours	
ME9052	**Gas Turbines and Jet Propulsion**	PEL	**3**	**0**	**0**	**3**	**3**
MEC303 (Fluid Mechanics) and MEC304 (Thermodynamics)		Course Assessment methods (Mid Term Examination(MTE),Continuous evaluation (CE) and end assessment (EA))					
NIL		MTE(25)+CE(15)+EA(60)					

Course Outcomes	CO1. **<u>To recall</u>** the fundamentals of Gas Turbines and thermodynamics of jet propulsion CO2: **<u>To analyse</u>** the performances of Axial flow and centrifugal flow GasTurbines CO3**:** **<u>To Predict</u>** the Performances ofAir Breathing and Non Air Breathing Engines (Solid Rocket Motors and Liquid Rocket Engines).

<u>Part-I: Gas Turbine:</u>

CO1 — Review of Basic thermodynamics and compressible flows. Euler's Turbomachinery Equations. 4

CO2 — Derivation of Euler Turbine equation for both axial and centrifugal turbines. Stage analysis of axial flow Turbine with and without swirl. Parametric analysis of Centrifugal flow gas turbines. 10

<u>Part-II: JET PROPULSION</u>

CO1 — **Air Breathing Engines:** Derivation of generalized equation/ expressions for thrust, Propulsive power, Ideal Brayton cycle and derivation of thermal efficiency of Ideal Brayton cycle. Propulsive efficiency, thermal efficiency and overall efficiency. Relation between themThermodynamic analysis of general air breathing jet engines: Specific Thrust, Fuel air ratio, TSFC(Thrust specific fuel consumption),. Condition for maximum overall efficiency. **6**

CO3 — Performance analysis of the following:
(a) Ramjet, (b) Turbojet (standard),Fan exhausted turbojet & Fan mixed turbojet
(c) Turbo prop. Effect of after burner on all the above. Related problems **10**

CO1 — **Non-air breathing engines:** Performance of Rocket vehicles such as Thrust, specific Impulse (I_{sp}), vehicle acceleration and burning time. **2**

CO3 — Type of chemical Rockets: Solid Rocket Motors and Liquid Rocket Engines. Elementary theory and performance characteristics of both types of chemical rockets. 4

Text Books, and/or reference material

Text Books:

1. Mechanics and thermodynamics of propulsion: P. G. Hill & C.R. Peterson.
2. Elements of Gas Turbine Propulsion- Jack D. Mattingly.

Reference Books:

1. Aircraft Propulsion : V. Babu

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
ME9053	**Theory of Combustion**	PEL	**3**	**0**	**0**	**3**	**3**
MEC303 (Fluid Mechanics) and MEC304 (Thermodynamics)		Course Assessment methods (Mid Term Examination(MTE),Continuous evaluation (CE) and end assessment (EA))					
NIL		MTE(25)+CE(15)+EA(60)					
Course Outcomes	CO1. **To recall** the fundamentals of fluid mechanics and thermodynamics related to combustion of solid and liquid propellant. CO2: **To analyse** the Flames theories for premixed and diffusion flame and theories of explosion and detonation. CO3**: To Predict** the combustion stability and combustion instabilities.						
CO1 CO2 CO3	Review of Basic fluid mechanics and thermodynamics related to combustion. Review of reaction kinetics. 10 Flame theories for premixed and diffusion flames. Explosion theories and Detonation theory. 12 Flame stabilization and combustion instabilities. Solid and liquid propellant combustion. Erosive burning of solid propellant grains. Deflagration to detonation transition. 14						
Text Books, and/or reference material	**Text Books:** **1. An introduction to combustion by Stephen R. Turn** **Reference Books:** 2. **Combustion Engineering** by Borman and Ragland						

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
ME9054	**Renewable Energy Sources**	PEL	3	0	0	3	3
	Topics Covered						**Hours**
	Energy scenario and renewable energy sources: global and Indian situation. Potential of non-conventional energy sources, economics. Solar Radiation: Solar thermal process, heat transfer devices, solar radiation measurement, estimation of average solar radiation. Solar energy storage: stratified storage, well mixed storage, comparison.						15
	Hot water system, practical consideration, solar ponds, Non-convective solar pond, extraction of thermal energy and application of solar ponds. Wind energy: The nature of wind. Wind energy resources and modelling. Geothermal energy: Origin and types of geothermal energy and utilization.						15
	OTEC: Ocean temperature differences. OTEC systems. Recent OTEC developments. Wave energy: Fundamentals. Availability Wave-energy conversion systems. Tidal energy: Fundamentals. Availability Tidal-energy conversion systems. ; Energy from biomass: Photosynthesis; Biomass resource; Utilisation of biomass.						10

Text Books, and/or reference material	Text Books: 1. Solar Energy Principle of Thermal Collection and Storage', S.P. Sukhatme TMG, 2. N.K.Bansal, Renewable Energy Source and Conversion Technology', TMG, 1989. Reference Books 1. G.L. Johnson, Wind energy systems, Prentice Hall Inc. New Jersey. 2.Non-conventional Energy Sources-- D. S. Chauhan and S. K. Srivastava

Department of Mechanical Engineering								
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
ME9055	**Power Plant Engineering**	PEL	3	0	0	3	3

	Topics Covered	**Hours**
	Introduction: Energy resources and their availability, types of power plants, selection of the plants, review of basic thermodynamic cycles used in power plants.	2
	Hydro Electric Power Plants: Rainfall and run-off measurements and plotting of various curves for estimating stream flow and size of reservoir, power plants design, construction and operation of different components of hydro-electric power plants, site selection, comparison with other types of power plants.	4
	Steam Power Plants: Flow sheet and working of modern-thermal power plants, super critical pressure steam stations, site selection, coal storage, preparation, coal handling systems, feeding and burning of pulverized fuel, ash handling systems, dust collection-mechanical dust collector and electrostatic precipitator.	10
	Steam generators and their accessories: High pressure Boilers, Accessories, Fluidized bed boiler.	4
	Condensers: Direct Contact Condenser, Surface Condensers, Effect of various parameters on condenser performance, Design of condensers, Cooling towers and cooling ponds	5
	Combined Cycles: Constant pressure gas turbine power plants, Arrangements of combined plants (steam& gas turbine power plants), re-powering systems with gas production from coal, using PFBC systems, with organic fluids, parameters affecting thermodynamic efficiency of combined cycles.	5
	Nuclear Power Plants: Principles of nuclear energy, basic nuclear reactions, nuclear reactors, BWR, CANDU, Sodium graphite, fast breeder, homogeneous; gas cooled. Advantages and limitations, nuclear power station, waste disposal.	5
	Power Plant Economics: load curve, different terms and definitions, cost of electrical energy, tariffs methods of electrical energy, performance & operating characteristics of power plants- incremental rate theory, input-output curves, efficiency, heat rate, economic load sharing, Problems.	5
Text Books, and/or reference material	Text Books: 1. Nag. P.K., Power Plant Engineering, 2nd Tata McGraw-Hill, 2011. 2. Power plant Technology by 'M.M.El-Wakil', McGraw Hill Com., 1985. Reference Books 1. Black, Veatch, Power Plant Engineering, CBS, 2005. 2. Power plant engineering by 'Arrora&Domkundwar', DhanpatRai& Sons, New Delhi, 2008	

<table>
<tr><th colspan="9">Department of Mechanical Engineering</th></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2" colspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>ME90**</td><td>HEAT AND FLUID FLOW IN POROUS MEDIA</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td colspan="2">3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="7">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">MEC 303 (Fluid Mechanics), MEC 304 (Engineering Thermodynamics) and MEC 403 (Heat and Mass Transfer)</td><td colspan="7">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">• CO1: To learn fundamental concept of modelling of a porous medium
• CO2: To learn the fundamental concept of heat conduction in porous medium
• CO3: To learn the fundamental concept of fluid flow in porous medium
• CO4: To learn the fundamental concept of forced and natural convections in porous medium.
• CO5: To learn the fundamental concept of radiative heat transfer in porous medium
• CO6: To apply porous medium modelling concept in biological systems.</td></tr>
<tr><td>Topics Covered</td><td colspan="8">I. Fundamental concept:
Definition, porosity, permeability; capillary models, hydraulic radius model, drag model for periodic structure; percolation and tortuosity, volume averaging, REV. [6]
II. Conduction in porous medium:
First law of thermodynamics, local thermal equilibrium, porous medium energy equation; second law of thermodynamics; effective thermal conductivity; thermal dispersion; thermal non equilibrium model (LTNE); transient heat conduction in porous media [8]
III. Fluid flow through porous medium:
Stokes flow and Darcy equation, Hazen-Dupuit-Darcy (HDD) model; high Reynolds number flows, macroscopic models, microscopic fluid dynamics; Brinkman model; semi-heuristic momentum equations. [10]
IV. Forced convection through porous medium:
Energy equation; forced convection in porous medium over a flat plate; forced convection in porous channel. [6]
V. Natural convection through porous medium:
Natural convection boundary layers—vertical and horizontal walls, natural convection with thermal gradient; non-Darcy, LTNE and heat generation effects. [6]
VI. Radiation in porous medium:
Radiative transfer equation (RTE), energy equation with radiation. [3]
VII. Mass transfer in porous medium:
Fick diffusion; local volume-averaged mass conservation equation; multicomponent flow; mass conservation in a mixture. [3]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="8">Text Books:
1. Principles of Heat Transfer in Porous Media, by M. Kaviany, Springer, New York (1999).
2. Essential of Heat and Fluid Flow through Porous Media, by Arunn Narasimhan, Anne Books, New Delhi, 2013.
3. Convection in Porous Media, by Nield, Donald A., Bejan, Adrian, Springer, 2013.
4. Modeling Phenomena of Flow and Transport in Porous Media, by Jacob Bear, Springer, 2018.</td></tr>
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