DEPARTMENT OF MECHANICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR -713209

Course on MASTER OF TECHNOLOGY

Specialization: FLUID MECHANICS AND HEAT TRANSFER

FULL TIME

Sl. No.	Subject Code	Name of the Subject	L	T	P	CP
Semester I						
1.	ME 1011	Viscous Fluid Flow	3	1	0	4
2.	ME 1012	Compressible Flow	3	1	0	4
3.	ME 1013	Mathematical Methods in Engineering	3	1	0	4
4.	ME 90**	Elective-I	3	1	0	4
5.	ME 90**	Elective-II	3	1	0	4
6.	ME 1061	Fluid Mechanics Laboratory -I	0	0	4	2
7.	ME 1062	Numerical Simulation Laboratory	0	0	4	2
					Total Credit	**24**
Semester II						
1.	ME 2011	Convective Heat and Mass Transfer	3	1	0	4
2.	ME 2012	Computational Fluid Flow and Heat Transfer	3	1	0	4
3.	ME 2013	Conduction and Radiation	3	1	0	4
4.	ME 90**	Elective-III	3	1	0	4
5.	ME 90**	Elective-IV	3	1	0	4
6.	ME 2061	CFD Laboratory	0	0	4	2
7.	ME 2062	Seminar –I (Non Project)	0	0	2	1
8.	ME 2063	Project-I	0	0	2	1
					Total Credit	**24**
Semester III						
1.	ME 3061	Project-II				11
2.	ME 3062	Project Seminar-I				2
					Total Credit	**13**
Semester IV						
1.	ME 4061	Project-III				11
2.	ME 4062	Project Seminar-II and Viva-Voce				3
					Total Credit	**14**
						TOTAL CREDIT POINT : 75

LIST OF ELECTIVE SUBJECTS		
Sl. No	**Subject Code**	**Name of the Subject**
1	ME 9041	Experimental Methods in Thermal Science
2	ME 9042	Numerical Methods and Computer Programming
3	ME 9043	Dynamical Systems
4	ME 9044	Hydro-Informatics Engineering
5	ME 9045	Fluid Power Systems and Control
6	ME 9046	Computer Aided Design of Thermal Systems
7	ME 9047	Renewable Energy
8	ME 9048	Micro and Nanoscale Heat Transfer
9	ME 9049	Gas Turbines and Jet Propulsion
10	ME 9050	Microfluidics
11	ME 9051	River Hydraulics & Engineering
12	ME 9052	High Performance Computins
13	ME 9053	Alternative Fuels & Systems
14	ME 9054	Advanced Computational Fluid Dynamics
15	ME 9055	Finite Element Methods for Fluid Dynamics
16	ME 9056	Perturbation Methods in Fluid Mechanics
17	ME 9057	Advanced Theory of Turbomachinery
18	ME 9058	Turbulence and Turbulent Flows
19	ME 9059	Conjugate Heat Transfer
20	ME 9060	Theory of Combustion
21	ME 9061	Fluid-Structure Interaction
22	ME 9062	Optimization Methods in Engineering
23	ME 9063	Lubrication Engineering

<table>
<tr><td colspan="8">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 1011</td><td>Viscous Fluid Flow</td><td>PCR</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">Fluid Mechanics,
Engineering Mathematics</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand boundary layer concept, creeping flow and hydrodynamic lubrication
CO2: To apply the laws of fluid motion
CO3: To learn concept of potential flow, hydrodynamic stability
CO4: Analysis of turbulence and turbulent flow.</td></tr>
<tr><td>Topics Covered</td><td colspan="6">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.
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.
Introduction to hydrodynamic stability, linear stability of plane Poiseuille flow, Orr-Sommerfeld equation, unsteady exact solution of Navier Stokes equation:</td><td>10
12
12</td></tr>
</table>

	Stokes first and second problem, Hydrodynamic theory of lubrication, thin film equation, slider bearing, Potential flow: basic flows, superposed flows, 2D steady inviscid constant density irrotational flow past a wedge 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 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, and turbulent kinetic energy.	12 10
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. 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	
ME 1012	**Compressible Flow**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Fluid Mechanics, Engineering Thermodynamics		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 CO3: Application of laws of Normal shock, oblique Shock and Prandtl-Meyer Flow. CO4: To design 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. 1-D wave motion: wave propagation – simple and finite waves, 2-D waves, and 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 Correlation of Fanno flow, Rayleigh flow, and a normal shock	16 24

	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.	

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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 1013	**Mathematical Methods in Engineering**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Engineering Mathematics		CT+EA					
Course Outcomes	CO1: To acquire an idea about advanced mathematical methods CO2: To apply mathematical methods in solving physical problems CO3: To learn analytical and numerical solution techniques for engineering problems						
Topics Covered	Vector and Tensor 10 Linear Algebra 10 Integral transform 8 Ordinary Differential Equation 8 Partial Differential Equation 8 Applied Numerical Techniques 12						
Text Books, and/or reference material	**Text Books:** 1. Advanced Engineering Mathematics- Erwin Kreyszig 2. Advanced Engineering Mathematics- Michael Greenberg 3. Mathematical Methods for Physics and Engineering; A Comprehensive Guide-K. Riley **Reference Books:** 1. Mathematical Methods for Physicists: A Comprehensive Guide: G. Arfken 2. Advanced Engineering Mathematics – K. A. Stroud						

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 1061	**Fluid Mechanics Lab**	**PCR**	**0**	**0**	**4**	**4**	**4**
Pre-requisites							
Viscous Fluid Flow, Convective Heat and Mass Transfer, Conduction and Radiation		CT+EA					

Course Outcomes	CO1: To learn the fundamentals of experimental techniques CO2: To perform experimental validation of theory in Fluid Mechanics and Heat transfer CO3: To learn the design and analysis of experiments
Topics Covered	To measure the wall static pressure and pressure distribution at different sections of a straight duct for incompressible flow of air. (4) To measure the wall static pressure and pressure distribution at different sections of a curved duct for incompressible flow of air. (4) To measure the wall static pressure and pressure distribution at different sections of a straight diffuser for incompressible flow of air. (4) To determine the thermal conductivity of brass using linear and radial conduction apparatus. (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) To determine the effectiveness of Parallel and Counter Flow Heat Exchanger.(4) To determine the value of Stefan Boltzmann Constant for radiation heat transfer. (4) To determination of convective heat transfer coefficient of a vertical tube due to natural convection and compare the same with theoretical value. (4)
Text Books, and/or reference material	**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

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>ME1062</td><td>Numerical Simulation Lab</td><td colspan="2">PEL</td><td></td><td>0</td><td>4</td><td>4</td><td>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">ME9011/ME1013</td><td colspan="7">CT+EA</td></tr>
<tr><td colspan="2">Course Outcomes</td><td colspan="7">CO1: Students will get idea of different programming languages
CO2: Students will learn to develop algorithm for different problems
CO3: Students will learn to write computer program to solve different engineering problems using various numerical methods</td></tr>
<tr><td colspan="2">Topics Covered</td><td colspan="7">Introduction to programming using high level language (C/C++/Fortran/MATLAB)
Computer programming for solving linear simultaneous equations, non-linear equations
Numerical differentiation and integration</td></tr>
</table>

	Solution of ordinary differential equations and solution of partial differential equations Eigen value problems, Boundary value, Initial value problems Problems as assigned by the respective teachers
Text Books, and/or reference material	**Text Books:** 1. Mat Lab Programming for Engineers By S. J. Chapman 2. Getting started with Mat lab By Rudra Pratap 3. Computer Programming in Fortran 90 and 95 by Rajaraman
	Reference Books: **1.** Numerical Methods By B. S. Grewal 2. Numerical Recipes in Fortran By W. H. Press, S. A. Teukolsky, W. T. Vetterling and B. P. Flannery

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 2011	**Convective Heat and Mass Transfer**	PEL	**4**	**0**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Engineering Thermodynamics, Heat and Mass Transfer		CT+EA					
Course Outcomes	CO1: To understand the basic concepts and principles of Heat and Mass Transfer CO2: To apply the laws of heat and mass transfer CO3: To learn about forced and natural convection heat transfer. CO4: Analyse the physics of turbulent models.						
Topics Covered	Governing Equations: Continuity, Momentum and Energy Equations and their derivations in different coordinate systems, Boundary layer Approximations to momentum and energy.						6
	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
	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
	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						14

	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 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 Mass transfer.	 8 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	

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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 2012	**Computational Fluid Flow & Heat Transfer**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Fluid Mechanics, Heat and Mass Transfer		CT+EA					

Course Outcomes	CO1: To introduce the physical and computational aspects of the governing equations of transport processes CO2: To introduce the stability of different numerical schemes CO3: To learn different discretization methods of computational fluid dynamics CO4: 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,	22

	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 **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.** 2. Numerical Heat transfer and Fluid flow – Patankar	

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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 2013	**Conduction and Radiation**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Fluid Mechanics, Engineering Thermodynamics Heat and Mass Transfer		CT+EA					

Course Outcomes	CO1: Acquire an idea about conduction transport mechanism CO2: To understand the physics of radiation CO3: Application of laws of radiation CO4:Analyse the gas radiation problems	
Topics Covered	Conduction: Steady and unsteady problems and their solutions in Cartesian, cylindrical and spherical coordinates.	6
	One 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 transforms. Problems involving change of phase. Inverse heat conduction, Micro scale heat transfer.	10
	Fins problems, pin fin, temperature distribution of pin fin. The effectiveness of	4

	pin fin. 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. Properties of Surfaces: Introduction, Black Body Radiation, Radiative properties of real surfaces. Radiation Exchange between surfaces: Introduction, Shape factor, Evaluation of shape factors, Radiation exchange between Gray surfaces enclosure Gas Radiation: Introduction, Beer's law, Emissivity and Absorptivity of gases and gas mixtures, Radiation and climate.	8 10 12 6
Text Books, and/or reference material	**Text Books:** 1. Title: Conduction and Radiation Author: K. Muralidhar, 2. Title: Heat Conduction Author: Sadik Kakac and Yaman Yener 3. Thermal Radiation Heat Transfer - Sigel R and Howell J 4. Radiative Heat Transfer - Michael F Modest	
	Reference Books: 1. Heat Conduction Author: Hahn, D. W. and Ozisik M. N.	

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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 2061	**CFD Laboratory**	**PCR**	**0**	**0**	**4**	**4**	**4**

Pre-requisites	
Basic knowledge in fluid dynamics, heat transfer and numerical methods	CT+EA
Course Outcomes	CO1: Writing computer programming in finite difference method (FDM) using high level language CO2: Learn to use 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.

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 2062	Seminar –I (Non Project)	PCR	**3**	**1**	**0**	**4**	**4**
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 advances 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	Seminar –I (Non Project): Topics decided by consultation with the supervisor						
Text Books, and/or reference material	**Text Books:** **Reference Books:**						

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 2063	Project –I	PCR	**3**	**1**	**0**	**4**	**4**
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 and Journals.						

Topics Covered	Project as decided based on literature survey with consultation with the supervisor
Text Books, and/or reference material	**Text Books:**
	Reference Books:

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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 3061	Project –II	PCR	**3**	**1**	**0**	**4**	**4**
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 and Journals.
Topics Covered	Project as decided based on literature survey with consultation with the supervisor
Text Books, and/or reference material	**Text Books:**
	Reference Books:

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	Project Seminar -I	PCR	**3**	**1**	**0**	**4**	**4**
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 advances 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	Project seminar: Progress of the project
Text Books, and/or reference material	**Text Books:**
	Reference Books:

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	Project -III	PCR	**3**	**1**	**0**	**4**	**4**
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 and Journals.						
Topics Covered	Project as decided based on literature survey with consultation with the supervisor						
Text Books, and/or reference material	**Text Books:** **Reference Books:**						

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 II and Viva-voce	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1: Ability to integrate technical question through all the years of study. CO2: Ability to express and communicate. CO3: Ability to evaluate technical confidence. CO4: Ability to validate the knowledge gained through years of study.						
Topics Covered	Project seminar II and Viva-voce						
Text Books, and/or reference material	**Text Books:** **Reference Books:**						

Electives

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 9041	Experimental Methods in Thermal Science	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Nil		CT+EA					
Course Outcomes	CO1: Acquire an idea about basic concepts of thermal measurements CO2: To learn the basics of data acquisition and data analysis CO3: To learn the measurement techniques for electrical signals, pressure, temperature, flow, velocity etc. CO4: To learn the fundamentals of wind tunnel measurements.						
Topics Covered	Basic concepts: Calibration, Standards, Dynamic Measurement, System response and Fourier Analysis 6 Data analysis: Error analysis, Uncertainty analysis, Statistical analysis, Curve fitting, Goodness of fit. 6 Measurement of electrical signals: Waveform measurements, Analog/digital meters, Amplifiers, Signal Conditioner, Oscilloscope, transducers 6 Measurements of physical variables: Pressure measurement 6 Flow measurement 8 Temperature measurement 6 Velocity measurements 6 Wind tunnel: Introduction, instrumentation and calibration of wind tunnels 6 Data acquisition and processing: Signal conditioning, Data transmission, ADC and DAC 6						
Text Books, and/or reference material	**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 by Foss et al. 3. Measurement systems—application and design, Doebelin, E. O.						

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			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 9043	**Dynamical System**	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Nil		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 behaviours (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 **12** 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

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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 9045	**Fluid Power Systems and Control**	PEL	**3**	**1**	**0**	**4**	**4**

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 with several components of hydraulic power system and techniques. CO3: Design hydraulic power packs using several components for engineering application CO4: To analyse hydraulic power system and troubleshoot.	
Topics Covered	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.	6
	Control Valves: types of valve and their configurations and symbols, spool valves, poppet valve, flapper nozzle valve, functioning of pressure control valves, direction control valve and flow control valves and their dynamic analysis.	10
	Fluid Power System and Dynamics: basic fluid power systems; dynamics of valve, 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

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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. 2. Fluid Power Control by Blackburn, J. F., G. Reethof, and J. L. Shearer, New York: Technology Press of M. I. T. and Wiley.

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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 9050	**MICROFLUIDICS**	PEL	**4**	**0**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))					
Fluid Mechanics Engineering Thermodynamics Heat and Mass Transfer		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: Analysis of Electro-hydro-dynamics problems CO4: Application by Molecular Dynamics Simulations	
Topics Covered	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 Microfluidics- Some Application Examples: Drug delivery, Diagnostics, Bio-sensing.	2
	Equations of Conservation, Navier Stokes Equation, Energy Equation, Pressure –driven Microflows: Exact solutions, Couette flow, Poiseuille flow.	10
	Some Examples of Unsteady Flows: Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel.	5
	Stokes Drag on a Sphere: Stokes drag on a sphere, Time-dependent flows, Two-phase flows. Lubrication Theory.	4
	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
	Surface Tension Driven Flows: Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect, Lab on a CD	9
	Introduction to Microfabrication: Materials, Clean room, Silicon crystallography,	2
	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. 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.	6
	Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size. Dielectrophoresis, Induced polarization and DEP ,	7

	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 Dispersion, Introduction to Nanofluidics, Introduction to Molecular Dynamics Simulations, Bio microfluidics, Nanofluidic Energy Conversion, Thin Film Dynamics.	11
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	

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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 9052	**High performance coputing**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Nil		CT+EA					

Course Outcomes		
Topics Covered	Program execution: Program, Compilation, Object files, Function call and return, Address space, Data and its representation	**6**
	Computer organization: Memory, Registers, Instruction set architecture, Instruction processing	**6**
	Pipelined processors: Pipelining, Structural, data and control hazards, Impact on programming	**6**
	Virtual memory: Use of memory by programs, Address translation, Paging	**6**
	Cache memory: Organization, impact on programming, virtual caches Operating systems: Processes and system calls, Process management	**6**
	Program profiling, File systems: Disk management, Name management, Protection	**6**
	Parallel architecture: Inter-process communication, Synchronization, Mutual exclusion, Basics of parallel architecture, Parallel programming with message passing using MPI and OpenMP]	**8**
	Parallel languages, Iterative solution of sparse linear systems, Fast Fourier transforms. Multigrid methods. Adaptive mesh refinement.	**8**
Text Books, and/or reference material	**Text Books:** 1. Title: Introduction to High Performance Computing for Scientists and Engineers, CRC Press, 2011, Authors: : Hager, G and Wellein, G, 2. Title: Introduction to High Performance Scientific Computing, Authors: Victor Eijkhout, Lulu.com, 2012.	
	Reference Books: 1. Title: Parallel Programming in C with MPI and OpenMP, Author: Quinn, M. J.,	

	TMH, 2003 2. Title: An Introduction to Parallel Programming, Author: Pacheo, Elsevier, 2011

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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 9057	**Advanced Theory of Turbomachinery**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Engineering Thermodynamics, Heat and Mass Transfer, Fluid Mechanics		CT+EA					
Course Outcomes	CO1: Acquire knowledge about roto-dynamic machines for producing or using power: CO2: Analysis of axial and radial flow gas/ steam and hydraulic turbines CO3: Recap of details of hydraulic pumps as roto-dynamic machine CO4: Design of axial flow and centrifugal compressor						
Topics Covered	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
	Dimensional Analysis: Similitude, Dimensionality, Similitude, Dimensionless Performance variables and similarity for turbo machinery, Compressible flow similarity, Specific speed and specific diameter. Exercise Problems.						4
	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
	Analysis of cascade forces, Lift and drag forces, Lift and drag co-efficient						4
	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
	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. 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
	Radial Flow Turbines: Introduction, types, IFR turbines, 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

	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. Centrifugal compressors: Introduction, kinematic and thermodynamic analysis of compressor stage, inlet casing, impeller, diffuser, conservation of enthalpy, optimum efficiency at inlet of pump/ compressor slip factor, compressor performance, choking in compressor stage. Introduction to 3-D flow in axial turbo-machines.	8 8 3
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	

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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 9063	**Lubrication Engineering**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Engineering 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 Bio-tribology of human joints CO5: Introduced to Micro-tribology for MEMS applications	
Topics Covered	**Surface topography:** Measurement of surface topography; Quantifying surface roughness; The topography of engineering surfaces. **Contact between surfaces:** Hertzian contact – sphere on sphere contact and cylinder on cylinder contact; Contact between rough surfaces. **Friction and Wear of contact surfaces:** Laws and Theories of friction and wear; Friction and Wear of different materials; Application to friction materials. **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. **Microtribology:** Surface forces and adhesion; Atomic force microscopy	3 5 10 20 8

	(AFM); Friction, wear and lubrication on atomic level; Applications to MEMS. **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	