NATIONAL INSTITUTE OF TECHNOLOGY, DURGAPUR -713209

DEPARTMENT OF MECHANICAL ENGINEERING

Course on MASTER OF TECHNOLOGY

Specialization: THERMAL ENGINEERING

FULL TIME

Sl. No.	Subject Code	Name of the Subject	L	T	P	CP
Semester I						
1.	ME 1021	Advanced Thermodynamics	3	1	0	4
2.	ME 1022	Advanced Heat Transfer	3	1	0	4
3.	ME 1023	Advanced Fluid Mechanics	3	1	0	4
4.	****	Elective-I	3	1	0	4
5.	****	Elective-II	3	1	0	4
6.	ME 1071	Thermal Engineering Laboratory-I	0	0	4	2
7.	ME 1072	Computational Laboratory	0	0	4	2
					Total Credit	**24**
Semester II						
1.	ME 2021	Advanced Energy Conversion	3	1	0	4
2.	ME 2022	Advanced I.C. Engine	3	1	0	4
3.	ME 2023	Analytical Methods in Heat Transfer and Fluid Flow	3	1	0	4
4.	****	Elective-III	3	1	0	4
5.	****	Elective-IV	3	1	0	4
6.	ME 2071	Thermal Engineering Laboratory-II	0	0	4	2
7.	ME 2072	Seminar –I (Non Project)	0	0	2	1
8.	ME 2073	Project-I	0	0	2	1
					Total Credit	**24**
Semester III						
1.	ME 3071	Project-II				11
2.	ME 3072	Project Seminar-I				2
					Total Credit	**13**
Semester IV						
1.	ME 4071	Project-III				11
2.	ME 4072	Project Seminar-II and Viva-Voce				3
					Total Credit	**14**
TOTAL CREDIT POINT : 75						

PART-TIME

Sl. No.	Subject Code	Name of the Subject	L	T	P	CP
Semester I						
1.	ME 1021	Advanced Thermodynamics	3	1	0	4
2.	ME 1022	Advanced Heat Transfer	3	1	0	4
3.	ME 1023	Advanced Fluid Mechanics	3	1	0	4
4.	ME 1071	Thermal Engineering Laboratory-I	0	0	4	2
					Total Credit	**14**
Semester II						
1.	ME 2021	Advanced Energy Conversion	3	1	0	4
2.	ME 2022	Advanced I.C. Engine	3	1	0	4
3.	ME 2023	Analytical Methods in Heat Transfer and Fluid Flow	3	1	0	4
4.	ME 2071	Thermal Engineering Laboratory-II	0	0	4	2
					Total Credit	**14**
Semester III						
1.	****	Elective-I	3	1	0	4
2.	****	Elective-II	3	1	0	4
3.	ME 1072	Computational Laboratory	0	0	4	2
					Total Credit	**10**
Semester IV						
1.	****	Elective-III	3	1	0	4
2.	****	Elective-IV	3	1	0	4
3.	ME 2072	Seminar –I (Non Project)	0	0	2	1
4.	ME 2073	Project-I	0	0	2	1
					Total Credit	**10**
Semester V						
1.	ME 3071	Project-II				11
2.	ME 3072	Project Seminar-I				2
					Total Credit	**13**
Semester VI						
1.	ME 4071	Project-III				11
2.	ME 4072	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 9071	Combustion Engineering
2.	ME 9072	Solar Thermal Systems
3.	ME 9073	Design of Thermal Systems
4.	ME 9074	Advanced Refrigeration and air-conditioning
5.	ME 9075	Gas Dynamics
6.	ME 9076	Turbo-machineries
7.	ME 9077	Measurement of Thermal Systems
8.	ME 9078	Design with Constructional Theory
9.	ME 9079	Engineering Optimization
10.	ME 9080	Renewable Energy Sources
11.	ME 9081	Steam and Gas Turbines
12.	ME 9082	Environmental Pollution Control
13.	ME 9083	Fuels, Combustion, and Emission Control
14.	ME 9084	Analysis of Thermal Power Cycles
15.	ME 9085	Heat Transfer Equipment Design
16.	ME 9086	Computational Methods in Thermal Engineering
17.	ME 9087	Power Plant Engineering
Following existing/ approved departmental electives to be offered in the proposed M. Tech course on "Thermal Engineering"		
	ME 9011	Applied Computational Methods
	ME 9014	Operation Research
	ME 9018	Finite Element Methods
	ME 9020	Knowledge Based Systems
	ME 9025	Modeling and Simulation of Mechanical Systems

SYLLABUS

<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>ME 1021</td><td>Advanced Thermodynamics</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</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">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Students will be able to understand the history, concepts, formulations and applications of Thermodynamics.
CO2: Students will be able to analyze and solve various practical problems on applications of Thermodynamics.
CO3: Students will be able to apply various solution techniques for solving new applied and theoretical problems.</td></tr>
<tr><td>Topics Covered</td><td colspan="6">1. First Law of Thermodynamics
1.1 First law for closed systems
1.2 First law for open systems
1.3 Structured presentation of the first law
1.3.1 Poincaré’s scheme
1.3.2 Carathéodory’s scheme
1.3.3 Keenan and Shapiro’s second scheme
1.3.4 Applications to vapor cycle</td><td>5</td></tr>
<tr><td></td><td colspan="6">2. Second Law of Thermodynamics
2.1 Second law for closed systems
2.2 Second law for open systems
2.3 Local thermodynamic equilibrium model
2.4 Entropy maximum and energy minimum principles
2.5 Carathéodory’s two axioms
2.5 A Heat Transfer man’s two axioms
2.6 Regenerative power generation in steam power plants</td><td>10</td></tr>
<tr><td></td><td colspan="6">3. Entropy Generation
3.1 Lost available work
3.2 Nonflow processes
3.3 Steady flow processes
3.4 Mechanisms of entropy generation
3.4.1 Heat transfer across a finite temperature difference
3.4.2 Flow with friction
3.4.3 Mixing
3.5 Entropy generation minimization
3.5.1 The method
3.5.2 Entropy generation number
3.5.3 Entropy generation in steam based power generation systems</td><td>7</td></tr>
<tr><td></td><td colspan="6">4. Exergy Analysis
4.1 Nonflow systems
4.2 Flow systems
4.3 Generalized exergy analysis
4.4 Exergy analysis of steam based power generation systems</td><td>7</td></tr>
<tr><td></td><td colspan="6">5. Irreversible Thermodynamics
5.1 Conjugate fluxes and forces
5.2 Linearized relations</td><td>3</td></tr>
</table>

	5.3 Reciprocity relations **6. Thermodynamic Relations** 6.1 The fundamental relation 6.1.1 Energy representation 6.1.2 Entropy representation 6.2 Legendre transform 6.3 Relation between thermodynamic properties 6.3.1 Maxwell's relations 6.3.2 Bridgman's table 6.3.3 Jacobians in thermodynamics **7. Stability of Thermodynamic Systems** 7.1 Stability conditions for thermodynamic potentials 7.2 Qualitative effect of fluctuations 7.3 Le Chatelier-Braun principle	7 5
Text Books, and/or reference material	**Text Books:** 1. Fundamentals of Engineering Thermodynamics by Moran, . Shapiro, Boettner, Bailey, Wiley 2. Thermodynamics An Engineering Approach by Cengel and Boles, McGraw Hill 3. 3. Advanced Engineering Thermodynamics by Bejan, Wiley	
	Reference Books: 1. Engineering Thermodynamics by P.K. Nag, McGraw Hill 2. Fundamentals of Thermodynamics by Sonntag, Borgnakke, Van Wylen, Wiley	

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 1022	Advanced Heat Transfer	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1: Students will be able to understand the history, concepts, formulations and applications of Heat Transfer. CO2: Students will be able to analyze and solve various practical problems on applications of Heat Transfer. CO3: Students will be able to apply various solution techniques for solving new applied and theoretical problems.	
Topics Covered	**1. Heat Conduction Fundamentals** 1.1 Coordinate systems 1.2 Nondimensional analysis of heat conduction equation 1.3 Heat conduction equation for anisotropic medium 1.4 Lumped and partially lumped formulations 1.5 Orthogonal functions, boundary value problems, Sturm-Liouville problem, and Fourier series **2. Separation of Variables** 2.1 Separation of variables in rectangular coordinate system 2.2 Separation of variables in cylindrical coordinate system 2.3 Separation of variables in spherical coordinate system **3. Approximate Analytic Methods** 3.1 Integral method 3.2 Approximate analytic method of residuals	4 4 4

	3.3 Galerkin method 3.4 Partial integration **4. Heat Convection Fundamentals** 4.1 Conservation equations 4.2 Rules of scale analysis 4.3 Heatlines for visualizing convection **5. Principle of Similarity to Heat Transfer** 5.1 Derivation of dimensionless parameter from the differential equations 5.2 Application of Pi-theorem to establish self-similarity and reduce partial differential equation to ordinary ones 5.3 Dimensional analysis **6. Boundary Layer Theory** 6.1 Fundamental problem in convective heat transfer 6.2 Similarity solutions 6.3 Other wall heating conditions **7. Heat Radiation Fundamentals** 7.1 Thermodynamic properties of thermal radiation 7.2 Ideal conversion of blackbody radiation 7.3 Applications to solar energy harvesting	7 7 8 10
Text Books, and/or reference material	**Text Books:** 1. Fundamental of Heat and Mass Transfer by Incropera and Dewitt, Wiley 2. Heat Transfer by Bejan, Wiley	
	Reference Books: 1. Heat Conduction by Kakac and Yener, CRC Press 2. Heat Convection by Kakac and Yener, CRC Press 3. Thermal Radiation Heat Transfer by Howell, Siegel,and Mengüç, CRC Press	

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 1023	**Advanced Fluid Mechanics**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		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. ▪ 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	8 10

	special cases. ▪ 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, 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, turbulent kinetic energy	10 8 8
Text Books, and/or reference material	**Text Books:** 1. Viscous Fluid Flow Author: White F.W., McGraw Hill 2. Boundary Layer Theory Author: Schlichting H, Springer 3. Viscous Flow Author: Sherman F., McGraw Hill	
	Reference Books: 1. Advanced Engineering Fluid Mechanics, Author: Muralidhar K.M., Biswas G., Narosa 2. An Introduction to Fluid Dynamics, Author: Batchelor, G.K., Cambridge 3. Incompressible Flow: Panton, R. L., Wiley	

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 2021	**Advanced Energy Conversion**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1: Students will be able to understand the history, concepts, formulations and applications of various Power Generation Systems. CO2: Students will be able to analyze and solve various practical problems on applications of Power generation systems. CO3: Students will be able to apply various solution techniques for solving new applied and theoretical problems.	
Topics Covered	Different energy resources, Energy Scenario in India, Introduction to Different Energy Conversion systems	3
	Advanced Coal Technologies (ACT), Pulverized fired and Fluidized bed combustion Technologies	9
	Gasification based energy conversion Technologies	6
	Advanced Power Generation Cycles: Supercritical power Plant, Cogeneration, combined cycle, Integrated Gasification Combined Cycle (IGCC)	8
	Biomass Energy conversion Technologies	2
	Direct Energy Conversion: Fuel Cell, Magneto HydroDynamic (MHD) system	8
	Nuclear Power Generation Technology	6
	Different CO_2 capture Technologies	2
Text Books, and/or	**Text Books:** 1. Principles of Energy Conversion by A.W. Culp, Tata McGraw Hill	

reference material	2. Energy Conversion edited by D. Goswami, F. Kreith, CRC Press
	Reference Books: 1. Fluidized Bed Technology: Principles and Applications by J.R. Howard, CRC Press 2. PEM Fuel Cells: Theory and Practice by FranoBarbir, Academic Press

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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 2022	**Advanced I.C. Engine**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1 Mechanism of internal combustion engines CO2 Knowledge of IC engine fuel CO3 Pollution from internal combustion engines CO4 Mechanism of gas turbines CO5 Outlines of alternative fuels	
Topics Covered	Thermodynamic Analysis of I.C. Engine Cycles. Effect of design and operating parameters on cycle efficiency. Modified fuel-air cycle considering heat losses and valve timing. Engine dynamics and torque analysis. Use of Combustion chart. Thermodynamic cycle with supercharging both S.I. and C.I. Engines. Limits of Supercharging. Methods of Supercharging and Superchargers.	13
	Fuels and combustion in S.I. engines, knocking and fuel rating. Energy balance, volumetric efficiency, measurement of indicated and brake power. Advanced theory of carburetion. Fuel Injection Systems for S.I. and C.I. Engines. Cooling of engine and governing of engine. Ignition system: conventional and electronic.	14
	Variable compression ratio engine. Theoretical analysis, methods of obtaining variable compression ratio, Wankel rotary combustion engine, Stratified charged engine, Methods of charge stratification, Dual fuel and Multi-fuel engines, Biofuels, Variable Valve timing engines, Exhaust emissions, its measurement and control. Fault diagnosis of S.I. Engines.	15
Text Books, and/or reference material	**Text Books:** 1. Fundamentals of I.C. Engine by Ganeshan, Tata McGraw Hill 2. I.C. Engines /RK Rajput/Laxmi Publications	
	Reference Books: 1. Internal Combustion Engines and Air Pollution, Edward F. Obert; 2. Fundamentals of I.C. Engines by H.B. Heywood, McGraw Hill	

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 2023	**Analytical Methods in Heat Transfer and Fluid Flow**	PCR	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1: Students will be able to understand the history, concepts, formulations and applications of Thermodynamics, Heat Transfer, and Fluid Mechanics. CO2: Students will be able to analyze and solve various practical problems on applications of Thermodynamics, Heat Transfer, and Fluid Mechanics. CO3: Students will be able to apply various analytical and semi-analytical solution techniques to practical and theoretical problems in order to compare them with the results of CFD and experimentation.	
Topics Covered	Variational formulation Fermat's principle Entropy generation minimization principle Constructal law Equipartition principle Method of intersecting asymptotes Fluid flow systems Conductive heat transport system Conjugate heat transport system Thermoelectric devices Finite-time heat engines	4 3 3 3 4 3 4 4 4 4 4
Text Books, and/or reference material	**Text Books:** 1. B. Weigand, Analytical Methods for Heat Transfer and Fluid Flow Problems, Springer, New York. 2. A. K. Pramanick, The Nature of Motive Force, Springer, New York.	
	Reference Books: 1. M. N. Ozisik, M. D. Mikhailov, Unified Analysis and Solution of Heat and Mass Diffusion, Dover, New York. 2. J. Fourier, Analytical Theory of Heat, Dover, New York.	

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 9011	**Applied Computational Methods**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1 CO2 CO3						
Topics Covered	Solution of linear simultaneous equations, matrix Inversion Solution of non-linear equation of one variable and solution of system of non-linear simultaneous equation Interpolation and curve fitting Numerical differentiation and integration Solution of ordinary differential equations and solution of partial differential equations Discrete and Fast Fourier transformation Analysis of Eigen value problems Application to different types of Boundary value, Initial value and Eigen value problems						6 6 4 4 5 5 4 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	
	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	
ME 9014	**Operation Research**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1: Students will be able to discuss the history, concepts, formulations and applications of operations research. CO2: Students will be able to analyze and solve conflicting problems on constrained linear optimization problems having single and multiple objectives. CO3: Students will be able to apply integer, dynamic programming methods for solving relevant problems.	
Topics Covered	Origin, growth, definition, methodology and application of OR	2
	Linear Programming, Mathematical Modeling, Graphical Method of Solution, Sensitivity Analysis	7
	Simplex Method, Big M and 2-Phase Methods, Duality in LP	7
	Transportation problem	3
	Assignment Problem	2
	Sequencing problem	3
	Queuing model and Simulation	3
	Competitive Decision Making, Game Theory	4
	Duality Theory and Sensitivity Analysis	3
	Integer Programming, Binary Integer Programming	4
	Dynamic Programming	3
	LP- Softwares	4
Text Books, and/or reference material	**Text Books:** 1. Introduction to Operations Research, Fredrick S. Hillier and Gerald J. Lieberman, 7th Edition, TMH, 2001 2. Industrial Engineering and Management-- O.P.Khanna 3. Operation Research for Engineers-- S. K.Basu, D. K.Pal, H.Bagchi 4. Operation Research: an Introduction-- D.S.Hira, P.K.Gupta	
	Reference Books: 1. Introduction to Operation Research-- C.M.Churchman, R.L.Aekaff, E.L.Arnoff 2. Operation Research in Production and Inventory Control-- F.Hanssmann	

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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 9016	**Mechatronics**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end					

	assessment (EA))
ME1001	CT+EA
Course Outcomes	CO1: Students will be able to identify the importance of amalgamation between the electronics and electro-mechanical systems. CO2: Students will be able to formulate and evaluate behavior of linear time continuous control systems. CO3: Students will be able to formulate the procedure for converting analog signals to digital form and vice-versa. CO4: Students will be able to describe signals and its processing by modern electronic methods. CO5: Students will be able to identify and critically evaluate current developments and emerging trends within the field of mechatronic systems.
Topics Covered	Mechatronic Systems: Introduction, Application of Mechatronics. 2 Sensors and Transducers - Brief review, Simple electronic elements & Operational Amplifiers. 4 Actuators: Pneumatic, Hydraulic, Electrical & Mechanical actuation system, Micro-actuators. 6 Modelling and Simulation of Physical System: System models, Dynamic responses of the system, System transfer functions. 6 Digital logic: Number systems, Boolean algebra, Logic gates - Application gate, Design of logic of digital logic gates. 6 Microprocessors and Micro-Controllers: Introduction, Microprocessor Architecture, Instruction codes, General requirements for implementation issues, Examples. 6 Programmable Logic Controllers: Basic structure, I/O processing, Programming, Timer, Inter relays and Counters. 8 Signal conditioning & Digital communication system: Basics of signal conditioning, Filtering, Data acquisition and Digital signal processing, Digital communication and Communication interface. 8 Mechatronic Systems, Case Studies. 10
Text Books, and/or reference material	**Text Books:** 1. Alciatore, D. G. and Histand, M. B., Introduction to Mechatronics and Measurement Systems, McGraw Hill Publications, 4th Edition, 2012. 2. Bolton, W., Mechatronics, Pearson Education India, 2008. 3. Gaonkar, R.S., Microprocessor Architecture, Programming and Applications with 8085, Penram Publishers India, 6th Edition, 2013.
	Reference Books: 1. Malvino, A. P., and Bates, D. J., Electronic Principles, TMH Publishing Company Ltd., New Delhi, 8th Edition, 2016. 2. Nise, N. N., Control Systems Engineering, 6th Edition, John Wiley & Sons, Inc., USA, 2011.

Department of Mechanical Engineering				
Course	Title of the	Program Core	Total Number of contact hours	Credit

Code	course	(PCR) / Electives (PEL)	Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME 9018	**Finite Element Methods**	PEL	**3**	**1**	**0**	**4**	**4**

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
NA	CT+EA

Course Outcomes	CO1 CO2 CO3	
Topics Covered	Brief review of mathematical concept, Matrix, gauss elimination method, Eigenvalue solution, Numerical Integration, Weighted residual methods, calculus of variation and Rayleigh-Ritz method.	5
	Introduction to finite element methods: Direct approach for standard discrete system. Potential Energy approach and virtual work approach, Variational approach and Galerkin's weighted residual approach for continuum.	6
	Interpolation polynomial – Lagrangian and Hermite. Natural Co-ordinates, Pascal triangle, concept of continuity, convergence criteria.	4
	Common elements: Bar elements, beam elements, triangular Elements, rectangular elements etc. Lagrangian Elements and Serendipity Elements. Concept of isoparametric elements.	5
	Concept of time-independent field problem and time independent field problem involving differential equations. Different types of Boundary conditions.	4
	Concept of mass matrix. Vibration problem and dynamic response problem.	4
	Application of finite element to structural problem: Plain stress / Plane strain problems, axisymmetric problems, plasticity and non-linear problems, Bending of plates, three- dimensional stress analysis problems, etc.	6
	Introduction to geometric non-linearity and material non-linearity in finite element analysis.	3
	Computer procedure for finite element analysis.	3
Text Books, and/or reference material	**Text Books:** 1. An Introduction to the Finite Element Method, J. N. Reddy 2.Text book of Finite Element analysis, P. Seshu	
	Reference Books: 1. The Finite Element Method in Engineering, S. S. Rao 2. The Finite Element Method its Basis and Fundamental , O. C. zienkiewich, R. L. Taylor, J. Z. Zhu	

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	
ME9019	**Robotics**	PEL	**3**	**1**	**0**	**4**	**4**

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Knowledge on Mechanisms	CT+EA
Course Outcomes	CO1: Students will be able to discuss the history, concepts and key components of robotics technologies. CO2: Students will be able to analyse and solve problems spatial transformation, forward and inverse kinematics, dynamics of robot manipulators, jacobian and singularities,

	joint trajectory for motion planning. CO3: Students will be able to describe and compare various robot grippers, sensors, actuators and controllers and their perception.
Topics Covered	Introduction to Robotics: Definition, Anatomy, Coordinate Systems, Work Envelopes, Basic structure, classification, applications of robots. 4 Robot Arm Kinematics: Frame transformation, Denavit-Hartenberg convention, Forward and Inverse kinematics of serial manipulator. 12 Linear and Angular Velocity of Links and Statics of Serial manipulator: Jacobians, Singularities. 8 Introduction to Dynamics of Serial Manipulators: Lagrange-Euler formulation. 8 Trajectory Planning of Manipulator: Joint space scheme, Cartesian space scheme. 6 Robot Sensors: Contact type, non-contact type, internal sensor, External sensor, Range sensor, Proximity sensor, touch sensor, Force and torque sensor, Encoders, etc. 10 Robot Grippers. 6 Robot Controllers 2
Text Books, and/or reference material	**Text Books:** 1. Fu, K., Gonzalez, R. and Lee, C. S. G., Robotics: Control, Sensing, Vision and Intelligence¸ McGraw- Hill, 1987. 2. Craig, J. J., Introduction to Robotics: Mechanics and Control, 2nd Edition, Addison-Wesley, 1989. 3. Saha, S. K., Introduction to Robotics, TMH Publishing Company Ltd., New Delhi, 2008. 4. Pratihar, D. K., Fundamentals of Robotics, Narosa Publishing House, India, 2017.
	Reference Books: 1. Ghosal, A., Robotics: Fundamental Concepts and Analysis, Oxford University Press, 2nd reprint, 2008. 2. Spong, M. W., Hutchison, S., and Vidyasagar, M., Robot Modeling and Control, Wiley India, New Delhi, 2006.

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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 9020	**Knowledge Based Systems**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1: Students will be able to understand need of soft computing techniques CO2: Students will be able to apply knowledge of different soft computing methods for solving engineering problems CO3: Students will be able to apply combined soft-computing techniques
Topics Covered	Introduction to expert systems – Definition, Need for expert systems, Methods of developing expert system – offline training/learning AND on-line training/learning Tools for developing expert systems – Hard Computing vs. Soft Computing. 6 Fuzzy Set Theory, Fuzzy Logic Controllers (FLC). 10 Neural Network (NN) Controllers – back propagation network, SOM, radial basis function networks, recurrent neural networks 10

	etc. Learning/optimisation tools – traditional (direct search and gradient based) and non-traditional (genetic algorithms (GAs), simulated annealing etc.) techniques. Combined techniques of soft computing – GA-FLC, GA-NN, NN-FLC, GA-FLC-NN Some Applications MatLab toolbox on GA, FLC and NN.	16 10 4
Text Books, and/or reference material	**Text Books:** 1. S.S. Rao, Engineering Optimization, Theory and Practics, 3rd Enlarged Edition, New Age International Publishers, New Delhi, 2010. 2. David E. Goldberg, Genetic Algorithms in Search, Optimization and Machine Learning, Addison-Wesley, Reading, Mass, 1989. 3. Simon Haykin, Neural Network and Learning Machines, 3rd Edition, Person Education, India 4. D. K. Pratihar, Soft Computing, Narosa Publishers, 2011 5. Timothy J. Ross, Fuzzy Logic with Engineering Applications, 3rd Edition, Wiley, 2011.	
	Reference Books: 1. Soft Computing and Its Applications, Vol. 1 & 2, Kumar S. Ray, Apple Academic Press	

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 9025	**Modeling and Simulation of Mechanical Systems**	PEL	**3**	**1**	**0**	**4**	**4**

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
NA	CT+EA

Course Outcomes	CO1 CO2 CO3	
Topics Covered	Elements of analytical mechanics; classification of constrains, Principles of virtual work, Lagrange's first equation. Lagrange's second equation. Hamilton's equations.	6
	Nonholonomic mechanical system dynamics, Routh and Gibb's equation, Kane dynamics with application to multi body systems.	6
	Modelling of systems involving continuous medium. Hamilton's principle for continuous medium. Elements of thermo-continuum and theory of constitutive relations.	8
	Fundamental topics in bond graph modelling of physical systems: Elements of multi-bond graphs, Thermo-mechanical bond graphs and continuous systems and other systems of typical interest. Introduction to various system simulation software.	11
	Basic elasticity theory. Strain Measurement Methods: Various types of strain gauges, Electrical Resistance strain gauges, semiconductor strain gauges, strain gauge circuits, transducer applications, recording instruments for static and dynamic applications.	9
Text Books, and/or reference material	**Text Books:** 1. Advanced Dynamics of Mechanical Systems, F.Cheli, G.Diana 2. Bondgraph in Modeling, Simulation& Fault Identification, Mukherjee, Karmakar, Samanta Ray	
	Reference Books:	

	1. System Dynamics, D. C. Karnopp, D. L. Margolis, R. C. Rosenberg 2. Modeling and Simulation of Dynamic Systems, R.L.Woods, K.L.Lawrence

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	
ME9029	**Optimization in Engineering Design**	PEL	**3**	**1**	**0**	**3**	**3**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes	CO1: Students will be able to describe and formulate optimization problems CO2: Students will be able to apply knowledge of different optimization methods for solving engineering problems CO3: Students will be able to differentiate between optimization methods and suggest a suitable technique applicable for a specific problem.
Topics Covered	Introduction: Engineering Application, Statement and Classification of the Optimization Problem, Classification, formulation procedures. 4 Classical Methods: Single Variable Optimization; Multivariable Optimization without any Constraints with Equality and Inequality Constraints, Kuhn–Tucker Conditions; Linear Optimization Methods, One-Dimensional Minimization Method. Unimodal Function. 6 Elimination Methods: Exhaustive search, Fibonocci and Golden Method. 4 Interpolation Method – Quadratic and Cubic Interpolation Method. 2 Unconstrained Minimization Method -- Univariate, Conjugate Directions, Steepest Descent (Cauchy) Method, Newton's Method, Marquardt Method, Quasi-Newton Method. 6 Constrained Minimization Method, Random Search Methods, Sequential Quadratic Programming. Basic Approach of the Penalty Function Method, Interior Penalty Function Method, Exterior Penalty Function Method. 5 Non-traditional Optimization Techniques - Genetic Algorithms. Simulated annealing. Particle swarm optimization. Ant Colony Optimization. Tabu search. 16 Reduction of size of an optimization problem. Scaling of design variables and constraints. 3 Multi-objective optimization problems, DPGA, NSGA 6 Introduction to optimization Toolbox in MATLAB. 4
Text Books,	**Text Books:** 1. S.S. Rao, Engineering Optimization, Theory and Practics, 3rd

and/or reference material	Enlarged Edition, New Age International Publishers, New Delhi, 2010. 2. Ashok D. Belegundu and Tirupathi R Chandrupatla, Optimization Concepts and Applications in Engineering, Pearson Education 1999, First India Reprint, 2002.
	Reference Books: 1. G. N. Vanderplaats, Numerical Optimization Techniques for Engineering Design with Applications, McGraw-Hill, New York, 1984. 2. R. L. Fox, Optimization Methods for Engineering Design, Addison-Wesley, Reading, Mass, 1971.

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 9071	**Combustion Engineering**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1 CO2 CO3	
Topics Covered	CYCLE ANALYSIS: Gas, steam and combined power cycles, refrigeration and air conditioning cycles, second law analysis.	5
	COMBUSTION THEORY : Fuels and types, combustion process, combustion mechanism, adiabatic flame temperature, flame propagation, stability, kinetics, combustion aerodynamics, gaseous detonations, flame ignition and extinction and condensed phase combustion, combustion in SI and CI engines, ignition and burning rate analysis.	10
	COMBUSTION SYSTEMS : Solid burning equipment's, stokers, pulverized coal burning systems, cyclone combustors, emissions, types of fluidized beds, fluidized bed combustion, fundamentals bubbling bed, gas and liquid burners types, gas turbine combustion systems, combustion modelling	10
	DESIGN OF COMBUSTION SYSTEMS; Design of combustion systems for boilers, furnaces, gas turbines and internal combustion engines, combustion chamber performance.	10
	PROPELLANT SYSTEMS; Types, theory of combustion, energy balance calculations	5
Text Books, and/or reference material	**Text Books:** 1. Stephen R Turns, "Introduction to Combustion: Concepts and Applications", McGraw Hill, 2. I G.L. Borman and K.N. Ragland, "Combustion Engineering", McGraw Hill, 1998.	
	Reference Books: 1. C.R. Ferguson and A.T. Kirk Patrick, "Internal Combustion Engines", John Wiley & Sons 2. D.Winterbone, "Advanced Thermodynamics for Engineers", Elsevier, 1996.	

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Course Code	Title of the course	Program Core (PCR) /	Total Number of contact hours				Credit
			Lecture	Tutorial (T)	Practical	Total	

		Electives (PEL)	(L)		(P)	Hours	
ME 9072	**Solar Thermal Systems**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1: Identify and explain the use of active, passive solar thermal systems. CO2: Develop an understanding that solutions to energy-related problems are complex involving sociological, economic, political and technological considerations, decisions and development. CO3: Gain insight into the issues surrounding solar energy development and use. CO4: Become knowledgeable about applications as they apply to commercial, residential and industrial markets.	
Topics Covered	INTRODUCTION – Solar energy option, specialty and potential – Sun – Earth – Solar radiation, beam and diffuse – measurement – estimation of average solar radiation on horizontal and tilted surfaces –problems – applications. Capturing solar radiation – physical principles of collection – types – liquid flat plate collectors –construction details – performance analysis – concentrating collection – flat plate collectors with plane reflectors – cylindrical parabolic collectors – Orientation and tracking – Performance Analysis.	12
	POWER GENERATION – solar central receiver system – Heliostats and Receiver – Heat transport system –solar distributed receiver system – Power cycles, working fluids and prime movers, concentration ratio.	7
	THERMAL ENERGY STORAGE: Introduction – Need for – Methods of sensible heat storage using solids and liquids – Packed bed storage – Latent heat storage – working principle – construction –application and limitations. Other solar devices – stills, air heaters, dryers, Solar Ponds & Solar Refrigeration, active and passive heating systems.	11
	DIRECT ENERGY CONVERSION: solid-state principles – semiconductors – solar cells –performance – modular construction, applications. Conversion efficiencies calculations.	5
	ECONOMICS: Principles of Economic Analysis – Discounted cash flow – Solar system – life cycle costs – cost benefit analysis and optimization – cost based analysis of water heating and photo voltaic applications.	5
Text Books, and/or reference material	**Text Books:** 1. Solar energy: Principles of Thermal Collection and Storage/ Sukhatme /TMH/2nd edition 2. Solar energy/ H. P. Garg/TMH	
	Reference Books: 1. Solar energy thermal processes/ Duffie and Beckman/John Wiley & Sons 2. Principles of solar engineering/ Kreith and Kerider/Taylor and Franscis/2nd edition	

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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 9073	**Design of Thermal Systems**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1: Latest methodologies for the design of thermal system CO2: Use of economics, system simulation and optimization method for thermal system CO3: Will learn exergy analysis and its application for thermal system CO4: Use of thermo-ecological parameters to assess various thermal system CO5: Modelling of energy system

Topics Covered	1. Introduction to Thermal System Design Introduction Life cycle design Thermal system design aspects Computer aided thermal system design	7
	2. Thermodynamics, Modelling, and Design Analysis Basic concepts and definition Control volume aspects Property relations Reacting mixtures and combustion Modelling and design of piping systems	7
	3. Thermodynamic Modelling of Polygeneration System Modelling of Power Generation Modelling of Cogeneration Modelling of Polygeneration	7
	4. Exergy Analysis Why exergy and energy analysis Balances for mass, energy and entropy Physical exergy Chemical exergy Exergy for systems and flows Exergy balance Reference environment Applications	7
	5. Applications with Thermodynamics and Heat and Fluid Flow Heat transfer Heat exchangers Trade-off between thermal and fluid flow irreversibility Application to power generation and refrigeration	7
	6. Economic Analysis Estimation of capital investment Principles of economic evaluation Cost of utility Profitability evaluation	
	7. Thermoeconomic Analysis and Evaluation Fundamental of thermoeconomics Thermoeconomic variable for component evaluation Costing considerations	7
	8. Thermoeconomic Optimization Introduction to optimization Cost optimal exergetic efficiency Optimization of heat exchanger networks Enhanced system optimization	7
	9. Exergy Method: Ecological Applications Cumulative exergy consumption Thermo-ecological cost Applications	7
Text Books, and/or reference material	**Text Books:** 1. Bejan A., Tsatsaronis G., Moran M.; Thermal design and optimization. Wiley. (Textbook) 2. Jaluria Y., Design and optimization of thermal system. CRC Press. 3. Szargut J., Exergy method: Technical and ecological applications. WIT Press. 4. Dincer I., Rosen MA., Exergy: Energy, environment and sustainable development. Elsevier.	

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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 9074</td><td>Advanced Refrigeration and Air-conditioning</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</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">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1
CO2
CO3</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Actual vapor compression system – Multi pressure vapour compression system – Environment friendly refrigerants – cascade system. 5
Absorption refrigeration system – Three fluid absorption system comparison of absorption with compression system - Analysis of multistage systems 10
Advanced psychometric calculations - Cooling load calculations Determination of U factor –short method calculation 10
Low temperature refrigeration - Joule Thompson coefficient – liquefaction of air – hydrogen –helium - Applications of cryogenics. 10
Room air distribution – Friction losses in ducts - Duct design, Air filters clean rooms – Air curtain 5</td></tr>
<tr><td rowspan="2">Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Arora, C.P., Refrigeration and Air Conditioning, 2nd ed., Tata McGraw-Hill, 2004.
2. Stoeker, W.P. and Jones, J.W., Refrigeration and Air Conditioning, 2nd ed., Tata McGraw- Hill, 1982.</td></tr>
<tr><td colspan="7">Reference Books:
1. Manohar Prasad, Refrigeration and Air Conditioning, New Age International, 1996.
2. Gosney, W.B., Principles of Refrigeration, Cambridge Uni. Press, 1982.</td></tr>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>ME 9076</td><td>Advanced Turbo-Machineries</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</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">NA</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1
CO2
CO3</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction, Classification of turbo machinery. Application of TT – theorem in turbo machinery. Incompressible fluid in turbomachines – Effects of Reynolds Number and Mach number. Energy transfer between a fluid and a rotor - Euler turbine equation – components of energy transfer impulse and Reaction – Efficiencies. ; Radial flow pumps and compressors – head capacity relationship – Axial flow pumps and compressors – Degree of reaction dimensionless parameters – Efficiency and utilization factor in Turbo Machinery. ; Thermodynamics of Turbo machine processes – Compression and expansion efficiencies – Stage efficiency – Infinitesimal stage and finite</td></tr>
</table>

	stage efficiencies. ; Flow of fluids in Turbo machines – flow and pressure distribution over an air foil section – Effect of compressibility cavitation's – Blade terminology- Cascades of blades – fluid deviation –Energy transfer of blades – Degree of reaction and blade spacing – Radial pressure gradient – Free vortex flow – losses in turbo machines; Centrifugal pumps and compressors – Inlet section – Cavitation flow in the impeller channel – flow in the discharge casing pump and compressor characteristic. ; Radial flow turbines –inward flow turbines for compressible fluids – inward flow hydraulic – velocity and flow coefficients gas turbine blading – Kaplan turbine – Pelton wheels.
Text Books, and/or reference material	**Text Books:** 1. Lee, 'Theory and Design of Steam and Gas Turbine', McGraw Hill, 1954. 2. Yahya, 'Turbines, Compressions & Fans', Tata McGraw Hill, 1983.
	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 9078	**Design with Constructal Theory**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1 CO2 CO3						
Topics Covered	Flow system design in accordance with constructal law 4 Distribution of imperfections 4 Design of simple flow configurations 4 Tree networks for fluid flow 4 Configurations for heat conduction 4 Multi-scale configurations 4 Multi-objective configurations 4 Vascularized materials 4 Configurations for electro-kinetic mass transfer 4 Mechanical and flow structures combined 4						
Text Books, and/or reference material	**Text Books:** 1. A. Bejan, S. Lorente, Design with Constructal Theory, Wiley, New York. 2. A. Bejan, Shape and Structure, from Engineering to Nature, Cambridge, Cambridge.						
	Reference Books: 1. Bejan, J. P. Zane, Design in Nature: How the Constructal Law Governs Evolution in Biology, Physics, Technology, and Social Organization, Anchor Books, New York. 2. A. Bejan, I. Dincer, S. Lorente, A. Miguel, H. Reis, Porous and Complex Flow Structures in Modern Technologies, Springer, New York.						

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 9079	**Engineering Optimization**	PEL	**3**	**1**	**0**	**4**	**4**

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
NA	CT+EA

Course Outcomes	CO1: Students will be able to describe and formulate optimization problems CO2: Students will be able to apply knowledge of different optimization methods for solving engineering problems CO3: Students will be able to differentiate between optimization methods and suggest a suitable technique applicable for a specific problem.	
Topics Covered	Introduction: Engineering Application, Statement and Classification of the Optimization Problem, Classification, formulation procedures. Classical Methods: Single Variable Optimization; Multivariable Optimization without any Constraints with Equality and Inequality Constraints, Kuhn–Tucker Conditions; Linear Optimization Methods, One-Dimensional Minimization Method. Unimodal Function. Elimination Methods: Exhaustive search, Fibonocci and Golden Method. Interpolation Method – Quadratic and Cubic Interpolation Method. Unconstrained Minimization Method -- Univariate, Conjugate Directions, Steepest Descent (Cauchy) Method, Newton's Method, Marquardt Method, Quasi-Newton Method. Constrained Minimization Method, Random Search Methods, Sequential Quadratic Programming. Basic Approach of the Penalty Function Method, Interior Penalty Function Method, Exterior Penalty Function Method. Non-traditional Optimization Techniques - Genetic Algorithms. Simulated annealing. Particle swarm optimization. Ant Colony Optimization. Tabu search. Reduction of size of an optimization problem. Scaling of design variables and constraints. Multi-objective optimization problems, DPGA, NSGA Introduction to optimization Toolbox in MATLAB.	4 6 4 2 6 5 16 3 6 4
Text Books, and/or reference material	**Text Books:** 1. S.S. Rao, Engineering Optimization, Theory and Practics, 3rd Enlarged Edition, New Age International Publishers, New Delhi, 2010. 2. Ashok D. Belegundu and Tirupathi R Chandrupatla, Optimization Concepts and Applications in Engineering, Pearson Education 1999, First India Reprint, 2002.	
	Reference Books: 1. G. N. Vanderplaats, Numerical Optimization Techniques for Engineering Design with Applications, McGraw-Hill, New York, 1984. 2. 2. R. L. Fox, Optimization Methods for Engineering Design, Addison- Wesley, Reading, Mass, 1971.	

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 9080	**Renewable Energy Sources**	PEL	**3**	**1**	**0**	**4**	**4**

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment

	(EA))
NA	CT+EA
Course Outcomes	CO1: Identify and explain the use of non-conventional energy systems. CO2: Develop an understanding to energy-related problems involving sociological, economic, political and technological considerations, decisions and development. CO3: Gain insight into the issues surrounding non-conventional energy sources development and use. CO4: Become knowledgeable about applications of non-conventional energy systems as they apply to commercial, residential and industrial markets.
Topics Covered	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; Utilization of biomass. — 10
Text Books, and/or reference material	**Text Books:** 1. Solar Energy Principle of Thermal Collection and Storage', S.P.SukhatmeTMG, 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

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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 9084	**Analysis of Thermal Power Cycles**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1 CO2 CO3						
Topics Covered	Steam power plant cycle - Rankine cycle - Reheat cycle - Regenerative cycle with one and more feed heaters - Types of feed heaters - Open and closed types - Steam traps types. — 10 Cogeneration - Condensing turbines - Combined heat and power – Combined cycles – Brayton cycle Rankine cycle combinations - Binary vapour cycle. — 10 Air standard cycles - Cycles with variable specific heat - fuel air cycle - Deviation from actual cycle. — 8 Brayton cycle - Open cycle gas turbine - Closed cycle gas turbine – — 6						

	Regeneration, Inter cooling and reheating between stages. Refrigeration Cycles - Vapour compression cycles - Cascade system Vapour absorption cycles -GAX Cycle.	6
Text Books, and/or reference material	**Text Books:** 1. Culp, R., Principles of Energy Conversion, McGraw-Hill, 2000. 2. Nag. P.K., Power Plant Engineering, 2nd Tata McGraw-Hill, 2002	
	Reference Books: 1. Nag. P.K., Engineering Thermodynamics, 3rd ed., Tata McGraw-Hill, 2005. 2. Arora, C.P., Refrigeration and Air Conditioning, 2nd ed., Tata McGraw-Hill, 2004.	

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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 9085	**Heat Transfer Equipment Design**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					

Course Outcomes	CO1 CO2 CO3	
Topics Covered	Constructional Details: Types, Fluid flow arrangements, parallel, counter and cross flow, shell and tube heat exchanger, Regenerators and recuperator, Condensers – Industrial applications;	6
	Heat Transfer: Modes of Heat Transfer, Overall heat transfer coefficient, Thermal resistance, Efficiency. Temperature Distribution and its implications, LMTD, effectiveness;	6
	Flow Distribution: Effect of Turbulence, Friction Factor, Pressure Loss, Orifice, Flow nozzle, Diffusers, Bends, Baffles, Effect of Channei Divergence, Manifolds;	8
	Stress in tubes, Headers sets and Pressure vessels: Differential Thermal Expansion, Thermal stresses, Shear stresses, Thermal sleeves, Vibration, Noise, types of failures. ;	10
	Design Aspects: Heat transfer and pressure loss flow configuration effect of baffles. Effect of deviations from ideality. Design of typical liquid-liquid, gas-gas-liquid heat exchangers. Design of cooling towers.	10
Text Books, and/or reference material	**Text Books:** 1. W.M. Kays and A.L. London., Compact Heat Exchangers', 3rd Ed., TMH,1984. 2. A.P. Frass and M.N.Ozisik, Heat Exchanger Design,'John Wiley & Sons Inc, 1965.	
	Reference Books: 1. D. Q Kern, Process Heat Transfer', McGraw Hill Book Co., 1984. 2. E.A.D. Saunders., ‗Heat Exchangers', Longman Scientific and Technical, New York, 1988.	

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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 9086	**Computational Methods in Thermal Engineering**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1 CO2 CO3						
Topics Covered	Introduction: Concepts of consistency, stability, and convergence of numerical schemes. Various finite difference and finite element methods and their applications to fundamental partial differential equations in engineering and applied sciences. Case studies selected from fluid mechanics and heat transfer. ;						10
	Finite Difference Method: Classification, Initial and Boundary conditions, Forward, Backward difference, Uniform and non-uniform Grids, Grid Independence Test. Basic finite difference schemes. Boundary treatments. Fourth order RK methods and Predictor-corrector methods and Nachsheim-Swigert iteration with applications to flow and heat transfer. ; Parabolic and hyperbolic problems: Model problems and stability estimates. Examples of the methods of lines.						15
	The Lax-Richtmyer equivalence theorem. Stability analysis. Discrete Fourier series. Von- Neumann stability analysis. Consistency, convergence and error estimates. Keller Box and Smith‘s method with applications to thermal boundary layers. ; Convection dominated problems: The failure of standard discretization, Up-winding and Higher order methods.						15
Text Books, and/or reference material	**Text Books:** 1. K.Muralidhar and T.Sundararajan, Computational Fluid Flow and Heat Transfer, Narosa Publishing House, New Delhi, 1995. 2. P.S. Ghoshdasdidar, Computer Simulation of flow and heat transfer TMH Ltd., 1998.						
	Reference Books: 1. S.V. Patankar, Numerical heat transfer fluid flow, Hemisphere Publishing Co, 1980. 2. D.A. Anderson, I.I. Tannehill, and R.H. Pletcher, Computational Fluid Mechanics and Heat Transfer, Hemisphere Publishing Corporation, New York, USA, 1984.						

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 9087	**Power Plant Engineering**	PEL	**3**	**1**	**0**	**4**	**4**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1 Study of power production CO2 Study of Hydro-electric power generation CO3 Study of some power plant related equipment's CO4 Study of Nuclear power generation CO5 Study of power plant economics						
Topics Covered	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 PWR, 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.	

SESSIONAL/LAB

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 1051	**Dynamics Laboratory**	PEL	**0**	**0**	**4**	**4**	**2**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
ME1001		CT+EA					
Course Outcomes	CO1: Acquire basic idea about the rotor balancing CO2: To understand the method of implementation of different control laws						
Topics Covered	Experiment on rotor balancing						12
	Experiment on Gyroscope						12

	Experiment on Digital Pendulum System 8 Experiment on Twin Rotor MIMO System 8 Problems as assigned by the respective teachers 16
Text Books, and/or reference material	**Text Books:** 1. Theory of Mechanisms and Machines, Ghosh, Mallik 2. Modern Control Engineering, Ogata
	Reference Books 1. Theory of Machines and Mechanisms, Shigley, Uicker 2. Automatic Control System, Kuo

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 1052 ME 1062 ME 1072	Applied Computational Methods Lab	PCR	0	0	4	4	4
Pre-requisites							
Basic knowledge in Numerical Methods		CT+EA					

Course Outcomes	● CO1: Concept of algorithm to write different numerical methods related to engineering problems. ● CO2: 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

Course Code	Title of the course	L-T-P	Credit	Developer
ME 1071	Thermal Engineering Lab-I	0-0-3	2	A.K. Pramanick, A. Layek & S.Karmakar

Experiments Covered

- Axial Heat conduction
- Forced Convection
- Radiation
- Boiler

Course Code	Title of the course	L-T-P	Credit	Developer
ME 1072	Computational Laboratory	0-0-3	2	A.K. Mitra & K. Khan

- Programming using high level language (C/C++/Fortran/MATLAB)
- Computer programming for solving linear simultaneous equations, non-linear equations.
- Numerical differentiation and integration
- 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

Course Code	Title of the course	L-T-P	Credit	Developer
ME 2071	Thermal Engineering Lab-II	0-0-3	2	A.K. Pramanick, A. Layek & S.Karmakar

Experiments Covered

- Radial Heat conduction
- Diesel Engine trial run
- Fluidization and Fluidized Bed Heat Transfer
- Moorse Test