NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF MECHANICAL ENGINEERING

Revised Curriculum and Syllabi

Program Name

Master of Technology in Thermal Engineering

Effective from the Academic Year: 2021-2022

Recommended by DPAC	: 06.08.2021
Recommended in PGAC	: 16.08.2021 & 01.10.2021
Approved by the Senate	: 22.08.2021

CURRICULUM

Sl. No.	Subject Code	Name of the Subject	L	T	S	C	H
Semester I							
1.	ME 1021	Advanced Thermodynamics	3	1	0	4	4
2.	ME 1022	Advanced of Heat Transfer	3	1	0	4	4
3.	ME 1023	Advanced Fluid Mechanics	3	1	0	4	4
4.	ME 90**	Specialization Elective - I	3	0	0	3	3
5.	ME 90**	Specialization Elective - II	3	0	0	3	3
6.	ME 1071	Heat Transfer Laboratory	0	0	4	2	4
7.	ME 1072	Computational Laboratory	0	0	4	2	4
					Total Credit	**22**	**26**
Semester II							
1.	ME 2021	Experimental Methods in Thermal Science	3	1	0	4	4
2.	ME 2022	Computational Methods in Thermal Science	3	1	0	4	4
3.	ME 2023	Mathematical Methods in Thermal Science	3	1	0	4	4
4.	ME 90**	Elective-III	3	0	0	3	3
5.	ME 90**	Elective-IV	3	0	0	3	3
6.	ME 2071	Thermal Engineering Laboratory	0	0	4	2	4
7.	ME 2072	Mini Project with Seminar	0	0	6	3	6
					Total Credit	**23**	**28**
Semester III							
1.	XX90XX	AUDIT LECTURES / WORKSHOPS	0	0	0	0	2
2.	ME 3071	DISSERTATION - I	0	0	24	12	24
3.	ME 3072	SEMINAR - NON-PROJECT / EVALUATION OF SUMMER TRAINING	0	0	4	2	4
					Total Credit	**14**	**30**
Semester IV							
1.	ME 4071	DISSERTATION - II / INDUSTRIAL PROJECT	0	0	24	12	24
2.	ME 4072	PROJECT SEMINAR	0	0	4	2	4
					Total Credit	**14**	**28**
TOTAL CREDIT POINT: 73							

LIST OF ELECTIVES

Sl. No.	Course Code	Course Title
1	ME9011	Applied Computational Methods
2	ME9014	Operations Research
3	ME9018	Finite Element Methods
4	ME9020	Knowledge Based Systems
5	ME9025	Modelling and Simulation of Mechanical Systems
6	ME9029	Optimization in Engineering Design
7	ME9045	Advanced Theory of Turbomachinery
8	ME9047	Multiphase Flow and Heat Transfer
9	ME9053	Theory of Combustion
10	ME9054	Renewable Energy Sources
11	ME9055	Power Plant Engineering
12	ME9071	Advanced Energy Conversion
13	ME9072	Advanced I. C. Engine
14	ME9073	Biofluid Mechanics
15	ME9074	Microscale Transport Phenomena
16	ME9075	Solar Thermal Systems
17	ME9076	Thermodynamics of Complex Systems
18	ME9077	Advanced Refrigeration and Air-Conditioning
19	ME9078	Design of Thermal Systems
20	ME9079	Heat Transfer Equipment Design
21	ME9080	Design with Constructal Law
22	ME9081	Analysis of Thermal Power Cycles

SYLLABUS

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	
ME1021	Advanced Thermodynamics	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes	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 the applications of Thermodynamics. CO3: Students will be able to apply various solution techniques for solving new applied and theoretical problems.	
	Topics Covered	**Hours**
	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	5
	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	10
	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	7

	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	7
	5. Irreversible Thermodynamics 5.1 Conjugate fluxes and forces 5.2 Linearized relations 5.3 Reciprocity relations	3
	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
	7. Stability of Thermodynamic Systems 7.1 Stability conditions for thermodynamic potentials 7.2 Qualitative effect of fluctuations 7.3 Le Chatelier-Braun principle	5
Text Books, and/or reference material	**Text Books:** 1. A. Bejan, Advanced Engineering Thermodynamics, Wiley, 2016. 2. E. P. Gyftopoulous, G. P. Beretta, Thermodynamics: Foundations and Applications, Dover, 2013. 3. A. B. Pippard, Elements of Classical Thermodynamics, Cambridge, 1957. 4. A. Thess, The Entropy Principle: Thermodynamics for the Unsatisfied, Springer, 2011. **Reference Books:** 1. R. S. Berry, V. Kazakov, S. Sieniutycz, Z. Szwast, A. M. Tsirlin, Thermodynamic Optimization of Finite-Time Processes, Wiley, 2000. 2. P. T. Landsberg, Thermodynamics and Statistical Mechanics, Dover, 2014. 3. M. Planck, Treatise on Thermodynamics, Dover, 2013.	

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	
ME1022	Advanced Heat Transfer	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		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 the applications of Heat Transfer. CO3: Students will be able to apply various solution techniques for solving new applied and theoretical problems.	
	Topics Covered	**Hours**
	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 3.3 Galerkin method 3.4 Partial integration	12
	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	22
	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	10
Text Books, and/or reference material	**Text Books:** 1. D. W. Hahn, M. N. Özisik, Heat Conduction, Wiley, 2012. 2. A. Bejan, Convection Heat Transfer, Wiley, 2013. 3. J. R. Howell, M. P. Menguc, R. Siegel, Thermal Radiation Heat Transfer, CRC, 2010. **Reference Books:** 1. V. S. Arpaci, Conduction Heat Transfer, Addison-Wesley, 1966. 2. T. Cebeci, P. Bradshaw, Physical and Computational Aspects of Convective Heat Transfer, Springer, 1998. 3. E. M. Sparrow, R. D. Cess, Radiation Heat Transfer, CRC, 2017.	

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	
ME1023	Advanced Fluid Mechanics	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes		CO1: Students will be able to understand the history, concepts, formulations and applications of Fluid Mechanics. CO2: Students will be able to analyze and solve various practical problems on the applications of Fluid Mechanics. CO3: Students will be able to apply various solution techniques for solving new applied and theoretical problems.					

	Topics Covered	Hours
	Velocity, Acceleration and Material Derivative, Local continuity equation, Vorticity and circulation, vorticity equation, rotational and irrotational flow, Stream function for 2-D and 3-D flows, Newton's momentum equation, Constitutive Relations, Newtonian and non-Newtonian fluids, Moving co-ordinate system	7
	Dimension analysis and similarities, Buckingham pi theorem, types of similarities	7
	Navier-Stokes equation, Exact solutions of Navier-Stokes equations	7
	Boundary layer theory, Integral form of Boundary layer equations	7
	Flow stability, Turbulent flows: Correlations and spectra, Averaged equations of motion, eddy viscosity and mixing length	6
	Compressible flow: Speed of sound, basic equations for 1-D flow, stagnation and sonic properties, normal and oblique shock wave, Mach cone	10
Text Books, and/or reference material	**Text Books:** 1. W. P. Graebel, Advanced Fluid Mechanics, Academic, 2007. 2. P. K. Kundu, I. M. Cohen, Fluid Mechanics, Academic, 2001. **Reference Books:** 1. R. A. Granger, Fluid Mechanics, Dover, 2012. 2. F. M. White, Viscous Fluid Flow, McGraw-Hill, 2017.	

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	
ME2021	Experimental Methods in Thermal Science	PCR	3	1	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Fluid Mechanics, Thermodynamics and Heat Transfer in UG Course	CT+EA

Course Outcomes	
	CO1: Students will be able to acquire knowledge about basic concepts of measurements and basic methods of data acquisition and data analysis. CO2: Students will be able to develop a theoretical understanding of various measurement techniques for thermal-and-transport-properties, thermofluid-dynamic variables and thermal radiation. CO3: Students will be able to learn the fundamentals of wind tunnel measurements and basics of flow-visualization methods for experimentation and future research.

Topics Covered	Hours
1. Basic concepts 1.1 Calibration 1.2 Standards 1.3 Dynamic measurement 1.4 System response 1.5 Fourier analysis 1.6 Distortion 1.7 Experiment planning	6
2. Data analysis 2.1 Error analysis 2.2 Uncertainty analysis 2.3 Statistical analysis 2.4 Graphical analysis and curve fitting 2.5 Multivariable regression 2.5 Goodness of fit	7
3. Physical laws of fluid mechanics and their application to measurement techniques 3.1 Introduction 3.2 Similarity analysis 3.2.1 Examples involving Reynolds number, drag coefficient, Strouhal number, and Fourier number 3.3 Open channel flow 3.4 Compressible flow 3.5 Interfacial phenomena 3.6 Survey of dimensionless parameters	5
4. Flow measurement and Flow-Visualization methods 4.1 Positive displacement methods 4.2 Flow-obstruction methods	5

	4.3 The sonic nozzle 4.4 Flow measurement by drag effects 4.5 Hot-wire and hot-film anemometers 4.6 Magnetic flow meters 4.7 Flow-visualization methods 4.7.1 The shadowgraph 4.7.2 The schlieren 4.7.3 The interferometer 4.7.4 The Laser Doppler Anemometer (LDA) 4.7.5 Smoke methods 4.7.6 Pressure probes and impact pressure in supersonic flow	
	5. Measurements of thermofluid-dynamic variables 5.1 Temperature measurement 5.2 Velocity measurement 5.3 Pressure measurement	6
	6. Measurements of thermal-and-transport-property 6.1 Viscosity measurement 6.2 Thermal conductivity measurement 6.3 Diffusion coefficient measurement 6.4 pH measurement 6.5 Humidity measurement 6.6 Calorimetry 6.7 Convection heat-transfer measurements 6.8 Heat-flux meters	7
	7. Measurement of thermal radiation 7.1 Measurement of thermal radiation 7.2 Measurement of emissivity, reflectivity and transmissivity 7.3 Measurements of solar radiation 7.4 Detection of nuclear radiation	4
	8. Wind tunnel 8.1 Introduction 8.2 Classification 8.3 Instrumentation and calibration of wind tunnels	4
Text Books, and/or reference material	**Text Books:** 1. Experimental methods for engineers by J. P. Holman 2. Fluid mechanics measurement -Edited by R. J. Goldstein. 3. Measurement systems—application and design by E. O. Doebelin 4. Experimentation, validation, and uncertainty analysis for engineers by H.W. Coleman and W.G. Steele Jr. **Reference Books:** 1. Handbook of experimental fluid mechanics by Tropea et al. 2. Handbook of heat transfer by Rohsenow et al. 3. Instrumentation, measurements and experiments in fluids by E. Rathakrishnan	

<table>
<tr><td rowspan="3">Course Code</td><td rowspan="3">Title of the course</td><td rowspan="3">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="3">Credit</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>ME2022</td><td>Computational Methods in Thermal Science</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, Thermodynamics and Heat Transfer in UG Course</td><td colspan="6">CT+EA</td></tr>
<tr><td colspan="2">Course Outcomes</td><td colspan="6">CO1: Students will be able to learn and implement solution procedures for solving linear and non-linear algebraic equations, ordinary differential equations (ODEs), and partial differential equations (PDEs) on a computer.
CO2: Students will be able to acquire working knowledge of computational complexity, accuracy, stability, and errors in solution procedures.
CO3: Students will be acquainted with the numerical techniques of obtaining solutions of complex equations like the Navier-Stokes equations, the analytical solutions to which are rarely available.</td></tr>
<tr><td colspan="2" rowspan="4"></td><td colspan="5">Topics Covered</td><td>Hours</td></tr>
<tr><td colspan="5">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.</td><td>10</td></tr>
<tr><td colspan="5">Finite Difference Method: Classification, Initial and Boundary conditions, Forward, Backward difference, Discretization of spatial and time derivatives using Taylor's series, Truncation error and order of discretization. Fourier (von Neumann) accuracy analysis. Uniform and non-uniform Grids, Grid Independence Test. Basic finite difference schemes. Boundary treatments. Euler explicit and implicit methods, Fourth order Runge-Kutta methods and Newton-Raphson method, Shooting method, 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.</td><td>17</td></tr>
<tr><td colspan="5">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. MacCormack Method and Beam–Warming Scheme for solving Compressible Navier–Stokes Equations.</td><td>17</td></tr>
</table>

Text Books, and/or reference material	**Text Books:** 1. Fundamentals of engineering numerical analysis by P. Moin, Cambridge University Press. 2. Computational methods for fluid dynamics by J. H. Ferziger, M. Perić, R. L. Street, Springer International Publishing 3. Computational fluid mechanics and heat transfer by R.H. Pletcher, J. C. Tannehill, D.A. Anderson, Hemisphere Publishing Corporation. 4. Computational fluid dynamics. The basics with applications by JD Anderson, McGraw Hill Education. 5. Numerical solution of partial differential equations: Finite Difference Methods by G. D. Smith, Oxford University Press. **Reference Books:** 1. Numerical heat transfer fluid flow by S.V. Patankar, Hemisphere Publishing Co. 2. Computational fluid flow and heat transfer by K.Muralidhar and T.Sundararajan, Narosa Publishing House. 3. Computer Simulation of flow and heat transfer by P.S. Ghoshdasdidar, TMH Ltd.

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	
ME2023	Mathematical Methods in Thermal Science	PEL	3	1	0	4	4
Course Outcomes		CO1: Students will be able to inculcate nonstandard analytical and semi-analytical methods especially in solving problems of physical interest in the area of thermodynamics, heat transfer, and fluid mechanics. CO2: Students will be able to master their skills especially non-computer based physical solution of problems of practical interest. CO3: This course eventually enable the students to abridge the apparently unmanifested gap between the experiment and the computation. CO4: This subject will train the students to obtain an intuitive validation of the results either obtained from the experiment or computation. CO5: This subject in essence guides the students to solve practical problems especially in the area of thermodynamics, heat transfer, and fluid mechanics.					
	Topics Covered						**Hours**
	1. Perturbation Methods in Heat Transfer 1.1 Regular perturbation expansions 1.2 Singular perturbation expansions 1.3 Method of strained coordinates 1.4 Method of matched asymptotic expansions vis-á-vis Bejan's method of intersecting asymptotes. 1.5 Examples with industrially important problems						5
	2. Similarity Analyses of Boundary Value Problems in Heat Transfer 2.1 Free parameter method 2.2 Group theory method						5

	2.3 Dimensional analysis vis-á-vis scaling analysis 2.4 Role of coordinate systems in similarity analyses 2.5 Examples with industrially important problems	
	3. Finite Fourier Transform (FFT) Method for Conduction and Diffusion Problems 3.1 Basis function as a solution for eigen value problems 3.2 Representation of an arbitrary function using orthonormal function 3.3 Self-adjoint eigen value problems 3.4 Point source solutions 3.5 Examples with industrially important problems	5
	4. Applications of Duhamel's Theorem in Heat Transfer 4.1 Duhamel's theorem for continuous time dependent boundary conditions 4.2 Treatment of discontinuity 4.3 Duhamel's theorem for internal heat generation 4.4 General statement of Duhamel's theorem 4.5 Examples with industrially important problems	4
	5. Applications of Green's Function for Solution of Heat Conduction Problems 5.1 Green's function approach for solving nonhomogeneous transient heat conduction 5.2 Determination of Green's function 5.3 Representation of point, line, and surface heat sources with delta functions 5.4 Products of Green's functions 5.5 Examples with industrially important problems	5
	6.Applications of Goodman's Heat Balance Integral Method for Heat Transfer Problems 6.1 Linear heat conduction equation with fixed boundaries 6.2 Temperature dependent thermal properties 6.3 Problems involving phase change 6.4 Unsteady convection problems 6.5 Examples with industrially important problems	5
	7. Applications of Conformal Mapping in Heat and Fluid Flow Problems 7.1 Selection on mapping functions 7.2 Steady state heat conduction in doubly connected regions 7.3 Transient heat transfer in isotropic and anisotropic media 7.4 Free streamline flow and the Hodograph method 7.5 Examples with industrially important problems	5
	8. Applications Variational Principles to Fluid Flow, Heat and Mass Transfer 8.1 The method of weighted residuals 8.2 Variational principles for Navier-Stokes equation 8.3 Least square interpretation of Weinstein's method 8.4 Relation to Galerkin and Finite Element Methods 8.5 Examples with industrially important problems	5
	9. Integral Transforms and Operational Methods in Heat Conduction 9.1 Properties of Laplace Transform 9.2 Inversion of the Laplace Transform 9.3 Integral Fourier and Hankel Transform 9.4 Kernels of Finite Integral Transforms 9.5 Solution of some differential equations with variable coefficients: Examples with industrially important problems	5
Text Books, and/or reference material	**Text Books:** 1. B. Weigand, Analytical Methods for Heat Transfer and Fluid Flow Problems, Springer, 2015. 2. G. Brenn, Analytical Solutions for Transport Processes: Fluid Mechanics, Heat and Mass Transfer, Springer, 2017. 3. A. G. Hansen, Similarity Analyses of Boundary Value Problems in Engineering, Prentice-	

Hall, 1964.
4. A. Aziz, T. Y. Na, Perturbation Methods in Heat Transfer, Hemisphere, 1984.
5. M. D. Van Dyke, Perturbation Methods in Fluid Mechanics, Parabolic Press, 1975.
6. M. N. Özişik, Boundary Value Problems in Heat Conduction, Dover, 1989.
7. K. D. Cole, J. V. Beck, A. Haji-Sheikh, B. Litkouhi, Heat Conduction Using Green's Functions, CRC Press, 2011.
8. A. V. Luikov, Analytical Heat Diffusion Theory, Academic, 1968.
9. M. A. Biot, Varitional Principles in Heat Transfer, Oxford, 1970.
10. H. S. Carslaw, Introduction to the Mathematical Theory of Conduction of Heat in Solids, Dover, 1945.
11. I. H. Sneddon, The Use of Integral Transforms, McGraw-Hill, 1972.
12. B. Finlayson, The Method of Weighted Residuals and Variational Principles, SIAM, 2014.
13. R. Schinzinger, P. A. A. Laura, Conformal Mapping: Methods and Applications, Dover, 2003.
14. A. K. Pramanick, The Nature of Motive Force, Springer, 2014.

Reference Books:

1. M. N. Ozisik, M. D. Mikhailov, Unified Analysis and Solution of Heat and Mass Diffusion, Dover, 2003.
2. J. Fourier, Analytical Theory of Heat, Dover, 2003.
3. L. I. Sedov, Similarity and Dimensional Methods in Mechanics, CRC, 2018.
4. J. C. Slattery, Momentum, Energy, and Mass Transfer in Continua, McGraw-Hill, 1972.
5. R. Courant, D. Hilbert, Methods of Mathematical Physics, Vol. I & II, Wiley-VCH, 2010.
6. Sir H. Jeffreys, Lady Jeffreys, Methods of Mathematical Physics, Cambridge, 1972.
7. A. N. Tikhonov, A. A. Samarski, Equations of Mathematical Physics, Dover, 2011.
8. S. Bergman, M. Schiffer, Kernel Functions and Elliptic Differential Equations in Mathematical Physics, Dover, 2005.
9. H. S. Carslaw, J. C. Jaeger, Operational Methods in Applied Mathematics, Dover, 1963.
10. S. Sieniutycz, Conservation Laws in Variational Thermo-Hydrodynamics, Kulwer, 1994.
11. I. J. Kumar, Recent Mathematical Methods in Heat Transfer, In: Advances in Heat Transfer, Editors: J. P. Hartnett, T. F. Irvive, Jr., Academic, 1972.
12. R. Bellman, G. Adomian, Partial Differential Equations: New Methods for Their Treatment and Solution, Springer, 1984.
13. S. G. Mikhlin, Mathematical Physics: An Advanced Course (Translated: Multilingua), North Holland, 1970.
14. A. Comte, The Philosophy of Mathematics (Translated: W. M. Gillespie), Dover, 2005.

SYLLABUS FOR 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	
ME9011	Applied Computational Methods	PEL	3	0	0	3	3

	Topics Covered	Hours
	Solution of linear simultaneous equations, matrix Inversion	6
	Solution of non-linear equation of one variable and solution of system of non-linear simultaneous equation	6
	Interpolation and curve fitting	4
	Numerical differentiation and integration	4
	Solution of ordinary differential equations and solution of partial differential equations	5
	Discrete and Fast Fourier transformation	5
	Analysis of Eigen value problems	4
	Application to different types of Boundary value, Initial value and Eigen value problems	4
	Brief discussion on software for numerical solution	2
Text Books, and/or reference material	**Text Books:** 1. Advanced Engineering Mathematics, E. Kreyszig 2. Numerical Methods for Scientist and Engineers, R. W. Hamming **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	
ME9014	Operations Research	PEL	3	0	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 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	Hours
	Origin, growth, definition, methodology and application of OR.	2

	Linear Programming, Mathematical Modelling, Graphical Method of Solution, Sensitivity Analysis.	7
	Simplex Method, Big M and 2-Phase Methods, Duality in LP.	8
	Transportation problem.	3
	Assignment Problem.	2
	Sequencing problem.	2
	Queuing model and Simulation.	3
	Competitive Decision Making, Game Theory.	3
	Duality Theory and Sensitivity Analysis.	3
	Integer Programming, Binary Integer Programming.	3
	Dynamic Programming.	3
	LP- Softwares.	3
Text Books, and/or reference material	**Text Books:** 1. Basu, S. K., Pal, D. K., Bagchi, H., Operation Research for Engineers, 2nd Edition, Oxford & IBH Publishing Co. Pvt. Ltd., 1998 2. Hillier, Fredrick S. and Lieberman, Gerald J., Introduction to Operations Research, 7th Edition, TMH, 2001. 3. Taha, H. A., Operation Research, McMillan Publishing Co., London, 1982. **Reference Books:** 1. Churchman, C. M., Ackoff, R. L., Arnoff, E.L., Introduction to Operation Research, Asia Publishing o., 1962 2. Hanssmann, F., Operations Research in Production and Inventory Control, John Wiley & Sons, Inc., London, 1962.	

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	
ME9018	Finite Element Methods	PEL	3	0	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 understand the basic concepts, formulations and applications of the mathematics of Finite Element Method. CO2: Students will be able to analyze and solve various practical problems on applications of critical uses of commercial software employing Finite Element Method as a code . CO3: Students will be able to apply various analytical, semi-analytical, and physical solution techniques to industrial and theoretical problems in order to compare them with the results of actual computation.					
	Topics Covered						**Hours**

	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	

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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	
ME9020	Knowledge Based Systems	PEL	3	0	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 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						**Hours**

	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.	5
	Fuzzy Set Theory, Fuzzy Logic Controllers (FLC).	7
	Neural Network (NN) Controllers – back propagation network, SOM, radial basis function networks, recurrent neural networks etc.	7
	Learning/optimisation tools – traditional (direct search and gradient based) and non-traditional (genetic algorithms (GAs), simulated annealing etc.) techniques.	12
	Combined techniques of soft computing – GA-FLC, GA-NN, NN-FLC, GA-FLC-NN Some Applications.	8
	MatLab toolbox on GA, FLC and NN.	3
Text Books, and/or reference material	**Text Books:** 1.D. K. Pratihar, Soft Computing, Narosa Publishers, 2011S.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. 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	
ME9025	Modelling and Simulation of Mechanical Systems	PEL	3	0	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 understand the history, concepts, formulations and applications of fundamental mechanics. CO2: Students will be able to analyze and solve various practical problems on applications system theoretic approach. CO3: Students will be able to apply the knowledge of Bondgraph technique to various industrial problems.					

	Topics Covered	**Hours**
	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. A. Mukherjee, R. Karmakar, Modelling and Simulation of Engineering Systems through Bondgraphs, Narosa, 2000. **Reference Books:** 1. J. U. Thoma, Simulation by Bondgrphs: Introduction to a Graphical Method, Springer, 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	
ME9029	Optimization in Engineering Design	PEL	3	0	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	**Hours**
	Introduction: Engineering Application, Statement and Classification of the Optimization Problem, Classification, formulation procedures.	3
	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.	5
	Elimination Methods: Exhaustive search, Fibonocci and Golden Method.	3
	Interpolation Method – Quadratic and Cubic Interpolation Method.	1
	Unconstrained Minimization Method -- Univariate, Conjugate Directions, Steepest Descent (Cauchy) Method, Newton's Method, Marquardt Method, Quasi-Newton Method.	5

	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
	Reduction of size of an optimization problem. Scaling of design variables and constraints.	1
	Multi-objective optimization problems, DPGA, NSGA	5
	Introduction to optimization Toolbox in MATLAB.	2
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. R. L. Fox, Optimization Methods for Engineering Design, Addison- Wesley, Reading, Mass, 1971.	

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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	
ME9045	Advanced Theory of Turbomachinery	PEL	3	0	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 work on application of Fluid Mechanics in designing various Turbo-Machineries. CO2: Students will be able to analyze and solve various practical problems on applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in fabricating various Turbo-Machineries. CO3: Students will be able to apply various dimensional analyses to solve industrial and theoretical problems.					
	Topics Covered						**Hours**

	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 stage efficiencies. ; Flow of fluids in Turbo machines – flow and pressure distribution over an airfoilsection – Effect of compressibility cavitations – 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 impller 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.	33
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:** 1. M. Gambini, M. Vellini, Turbomachinery: Fundamentals, Selection, and Primary Design, Springer, 2020.	

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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	
ME9047	Multiphase Flow and Heat Transfer	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	CO1: Leads students toward a clear understanding and firm grasp of the basic principles of multi phase flow and heat transfer. CO2: Understands the fluid-dynamic involved in convection and multi-phase heat transfer. CO3: Performs elementary analysis of most gas-liquid two-phase systems and prepares to use more advanced models. CO4: Equips the student with the analytical model to apply the fundamentals to a wide variety of complex engineering problems, formulate them and interpret the results. CO5: Student can analyze Hydrodynamics of three phase flows and compare two phase flow situations.						

	Topics Covered	Hours
	Introduction, Flow Regimes.	5
	Homogeneous Flow, Separated Flow.	4
	Condensation.	2
	One dimensional steady separated flow model.	6
	Flow in which inertia effects dominate, energy equations.	3

	The separated flow model for stratified and annular flow.	2
	General theory of drift flux model.	3
	Application of drift flux model to bubbly and slug flow.	4
	Hydrodynamics of solid-liquid and gas-solid flow.	4
	An introduction to three phase flow.	3
	Fluid-Population Balance Technique, Volume of Fluid Method, Lattice Boltzmann Model.	6
Text Books, and/or reference material	**Text Books:** 1. Ghiaasiaan, S. M., Two-Phase flow, Boiling, and Condensation, Cambridge University Press. 2. Brennen, C.E., Fundamentals of Multiphase Flow, Cambridge University Press Collier, J. G. and Thome, J. R., Convective Boiling and Condensation, 3rd ed., Oxford University Press 3. Wallis, G.B., One Dimensional Two Phase Flow, McGraw Hill Higher Education. 4. Hewitt, G.F., Measurement of Two Phase Flow Parameters. 5. Govier, G.W., and Aziz, k., Flow of Complex Mixtures. **Reference Books:** 1. Hetsroni, G., Handbook of Multiphase systems.	

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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	
ME9053	Theory of Combustion	PEL	3	0	0	3	3
Pre-requisites		Continuous assessment (CA), Mid-term (MT), End-term					
Courses in thermodynamics and fluid mechanics		Evaluation: CA+MT+ET					
Course Outcomes	CO1: Understand the fundamentals of reacting systems CO2: Correlate thermodynamics, fluid mechanics and chemical kinetics CO3: Model the reacting systems CO4: Describe combustion driven instabilities CO5: Calculate flame properties and emission characteristics CO6: Appreciate the measurement techniques of a combustion system						
	Topics Covered						**Hours**
	Introduction: Combustion and its application, Approaches to Combustion study, Types of combustion.						1
	Thermodynamics of reacting systems: Review of Thermodynamics, Fuels, Stoichiometry, First law of reacting system, Enthalpy of formation, enthalpy of combustion, Adiabatic flame temperature, Chemical equilibrium, Equilibrium constants, Full Equilibrium model, Water Gas equilibrium, Case studies, Oxyfuel combustion, Syngas combustion.						6
	Chemical kinetics: Global and elementary reactions, collision theory, Chain reactions, Chemical time scales, Kinetic rate coefficients, Multistep mechanism, Steady state approximation, Partial equilibrium approximation.						5
	Simple reactor models: Constant pressure reactors, Constant volume reactors, Well stirred reactors, Plug flow reactors.						3
	Conservation equations: Reynolds transport theorem, Mass, Momentum, Energy, and Species conservation, Entropy balance equation.						3

	Laminar Premixed flames: Rankine-Hugoniot relations, Detonation and deflagration waves, Flame propagation and flame speed, Determination of flame speed, Factors affecting flame speed, Flame quenching and Ignition, Flame stability, Lift-off, Blowout, Flashback.	6
	Laminar Non-premixed flames: Diffusion controlled systems, Conserved scalar formulation, Shvab-Zeldovich formulation, Burke-Schumann flame, Counter-flow flame, Partially premixed flame, Soot generation.	6
	Droplet and spray combustion: Spray formation, Evaporation and combustion of a single droplet, High pressure-convective effects, Spray combustion, Gas phase combustion, and droplet equations.	4
	Combustion emission: Emissions of pollutant gases, Emissions of greenhouse gases, Emissions of Particulate matter, Abatement of emission, Emission quantification.	3
	Combustion diagnostics: Flow field measurement, Temperature measurement, Species and concentration measurements, Pressure measurement, soot measurement, Droplet and spray measurement.	4
Text Books, and/or reference material	**Text Books:** 1. A. Mukhopadhyay and S. Sen, “Fundamentals of Combustion Engineering”, CRC Press, Taylor & Francis Group. 2. Stephen R. Turns, “An Introduction to Combustion: Concepts and Applications”, McGraw Hill **Reference Books:** 1. C. K. Law, “Combustion Physics”, Cambridge. 2. K. K. Kuo, “Principles of Combustion”, John Wiley and Sons Inc.	

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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>ME9054</td><td>Renewable Energy Sources</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</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">NA</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1. Understand of renewable and non-renewable sources of energy
CO2. Gain knowledge about principle of various solar energy systems
CO3. Understand the principle of wind energy system.
CO4. Develop capability to do basic design of bio gas plant.
CO5. Understand the applications of different renewable energy sources like oceanthermal, hydro, geothermal energy etc.</td></tr>
<tr><td colspan="7">Topics Covered</td><td>Hours</td></tr>
<tr><td colspan="7">INTRODUCTION TO ENERGY STUDIES Introduction, Energy science and Technology, Forms of Energy, Importance of Energy Consumption as Measure of Prosperity, Per Capita Energy Consumption, Roles and responsibility of Ministry of New and Renewable Energy Sources, Needs of renewable energy, Classification of Energy Resources, Conventional Energy Resources, Non-Conventional Energy Resources, World Energy Scenario, Indian Energy Scenario.</td><td>8</td></tr>
</table>

SOLAR ENERGY Introduction, Solar Radiation, Sun path diagram, Basic Sun-Earth Angles, Solar Radiation Geometry and its relation, Measurement of Solar Radiation on horizontal and tilted surfaces, Principle of Conversion of Solar Radiation into Heat, Collectors, Collector efficiency, Selective surfaces, Solar Water Heating system, Solar Cookers, Solar driers, Solar Still, Solar power, Solar Photovoltaic fundamentals, Characteristics, Classification, Construction of module, panel and array. Solar PV Systems (stand-alone and grid connected), Solar PV Applications. Government schemes and policies.	10
WIND ENERGY Introduction, History of Wind Energy, Wind Energy Scenario of World and India. Basic principles of Wind Energy Conversion Systems (WECS), Types and Classification of WECS, Parts of WECS, Power, torque and speed characteristics, Electrical Power Output and Capacity Factor of WECS, Stand alone, grid connected and hybrid applications of WECS, Economics of wind energy utilization, Site selection criteria, Wind farm, Wind rose diagram	8
BIOMASS ENERGY Introduction, Biomass energy, Biomass fuels, Biomass energy conversion technologies and applications, Urban waste to Energy Conversion, Biomass Gasification, Types and application of gasifier, Biomass to Ethanol Production, Biogas production from waste biomass, Types of biogas plants, Factors affecting biogas generation, Energy plantation, Environmental impacts and benefits, Future role of biomass, Biomass programs in India.	8
HYDRO POWER AND OTHER RENEWABLE ENERGY SOURCES Hydropower Capacity and Potential, Small hydro, Environmental and social impacts. Tidal Energy Capacity and Potential, Principle of Tidal Power, Components of Tidal Power Plant, Classification of Tidal Power Plants. Principle of OTEC system, Methods of OTEC power generation. Geothermal Energy Capacity and Potential, Resources of geothermal energy.	8

Text books, and/ or reference material	**Text Books:** 1. Solar Energy Principle of Thermal Collection and Storage', S.P.Sukhatme/TMG, 2. N.K.Bansal, Renewable Energy Source and Conversion Technology/TMG **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	
ME9055	Power Plant Engineering	PEL	3	0	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 understand the history, concepts, formulations and applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in the Production of Power.					

	CO2: Students will be able to analyze and solve various practical problems on applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in the designing of various components of Power Plants. CO3: Students will be able to apply various analytical and graphical techniques to solve industrial problems.	
	Topics Covered	**Hours**
	Introduction: Energy resources and their availability, types of power plants, selection of the plants, review of basic thermodynamic cycles used in power plants.	2
	Hydro Electric Power Plants: Rainfall and run-off measurements and plotting of various curves for estimating stream flow and size of reservoir, power plants design, construction and operation of different components of hydro-electric power plants, site selection, comparison with other types of power plants.	4
	Steam Power Plants: Flow sheet and working of modern-thermal power plants, super critical pressure steam stations, site selection, coal storage, preparation, coal handling systems, feeding and burning of pulverized fuel, ash handling systems, dust collection-mechanical dust collector and electrostatic precipitator.	10
	Steam generators and their accessories: High pressure Boilers, Accessories, Fluidized bed boiler.	4
	Condensers: Direct Contact Condenser, Surface Condensers, Effect of various parameters on condenser performance, Design of condensers, Cooling towers and cooling ponds	5
	Combined Cycles: Constant pressure gas turbine power plants, Arrangements of combined plants (steam& gas turbine power plants), re-powering systems with gas production from coal, using PFBC systems, with organic fluids, parameters affecting thermodynamic efficiency of combined cycles.	5
	Nuclear Power Plants: Principles of nuclear energy, basic nuclear reactions, nuclear reactors, BWR, CANDU, Sodium graphite, fast breeder, homogeneous; gas cooled. Advantages and limitations, nuclear power station, waste disposal.	5
	Power Plant Economics: load curve, different terms and definitions, cost of electrical energy, tariffs methods of electrical energy, performance & operating characteristics of power plants- incremental rate theory, input-output curves, efficiency, heat rate, economic load sharing, Problems.	5
Text Books, and/or reference material	**Text Books:** 1. Nag. P.K., Power Plant Engineering, 2nd Tata McGraw-Hill, 2011. 2. Power plant Technology by 'M.M.El-Wakil', McGraw Hill Com., 1985. **Reference Books:** 1. Black, Veatch, Power Plant Engineering, CBS, 2005. 2. Power plant engineering by 'Arrora&Domkundwar', DhanpatRai& Sons, New Delhi, 2008	

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<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2" colspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>ME9071</td><td>Advanced Energy Conversion</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td colspan="2">3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="7">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="7">CT+EA</td></tr>
<tr><td colspan="2">Course Outcomes</td><td colspan="7">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.</td></tr>
<tr><td rowspan="9"></td><td colspan="7">Topics Covered</td><td>Hours</td></tr>
<tr><td colspan="7">Different energy resources, Energy Scenario in India, Introduction to Different Energy Conversion systems</td><td>2</td></tr>
<tr><td colspan="7">Advanced Coal Technologies (ACT), Pulverized fired and Fluidized bed combustion Technologies</td><td>7</td></tr>
<tr><td colspan="7">Gasification based energy conversion Technologies</td><td>4</td></tr>
<tr><td colspan="7">Advanced Power Generation Cycles: Supercritical power Plant, Cogeneration, combined cycle, Integrated Gasification Combined Cycle (IGCC)</td><td>5</td></tr>
<tr><td colspan="7">Biomass Energy conversion Technologies</td><td>2</td></tr>
<tr><td colspan="7">Direct Energy Conversion: Fuel Cell, Magneto HydroDynamic (MHD) system</td><td>6</td></tr>
<tr><td colspan="7">Nuclear Power Generation Technology</td><td>5</td></tr>
<tr><td colspan="7">Different CO_2 capture Technologies</td><td>2</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="8">Text Books:
1.Principles of Energy Conversion by A.W. Culp, Tata McGraw Hill
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
2PEM Fuel Cells: Theory and Practice by FranoBarbir, Academic Press</td></tr>
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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	
ME9072	Advanced I.C. Engine	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes		CO1: Understand the history, concepts, formulations and applications of various I. C. Engines CO2: Analyze and solve various practical problems on applications of I. C. Engines CO3: Apply various solution techniques for solving new applied and theoretical problems.					

	Topics Covered	Hours
	Introduction: Classification, Basic geometry, Operating cycle (4 stroke and 2 stroke), SI and CI engine, Multi-cylinder configurations.	2
	Fuels and Thermochemistry: Combustion and flames, Classification of flames, Thermodynamic properties of a mixture, Composition of air and fuels, Composition Stoichiometry, Air fuel ratio, Equivalence ratio, First law of Thermodynamics and combustion, Enthalpy of formation, Heating values, Adiabatic flame temperature, Combustion Efficiency.	6
	Mixture preparation of SI engine: Mixture requirements, Mixture formation, Fuel characteristics, Central fuel injection, Port fuel injection, Direct fuel injection,	4
	Combustion in SI engines: SI engine combustion process, Knocking, Flame structure, Spark ignition systems, Ignition fundamentals, Standard Ignition systems, Abnormal combustion, fuel factors in knocking, Octane number, knock suppression.	6
	Combustion in CI engines: Types of Diesel combustion systems, Concept of ignition delay, Fuel Injection, Spray structure, Factors affecting ignition delay, Fuel properties on ignition delay, Biodiesel	4
	Application of diesel engines in power field, merit and demerits of diesel engine power plants, layout of diesel engine power plants.	2
	Supercharging/Turbo-charging: Objectives, Limitations, Methods and Types, Different arrangements of turbochargers and superchargers	4
	Non-Conventional Engines: Variable Compression Ratio (VCR) Engine, Stratified Charge Engine, Dual Fuel Engine, Free Piston Engine, Wankel Engine	4
	Basics of Electronic Engine Controls: Electronic Control module (ECM), Inputs required and output signals from ECM, Sensors: Throttle Position, Inlet Air Temperature, Coolant Temperature, Crankshaft Position, Camshaft Position, Mass Air flow and Exhaust Gas Oxygen sensors, their construction and importance in ECM. Electronic Spark control, Air Management system, Idle speed control	4
	Alternative Fuels Alcohol - Hydrogen - Natural Gas and Liquefied Petroleum Gas – Biodiesel- Biogas - Producer Gas - Properties - Suitability - Engine Modifications - Merits and Demerits as fuels.	4
	Engine Exhaust Emission and its control Constituents of exhaust emission at its harmful effect on environment and human health, Formation of NOx, HC, CO and particulate emissions, Methods of controlling emissions; Catalytic convertors, particulate traps, Exhaust Gas Recirculation, EURO and BHARAT norms.	4

Text Books, and/or reference material	**Text Books:** 1. Fundamentals of I.C.Engine by Ganeshan, Tata McGraw Hill 2. Fundamentals of I.C. Engines by H.B.Heywood, McGraw Hill **Reference Books:** 1.I.C.Engine Theory and Practices, Vol.I& II C.F.Taylor, MIT Press 2. I.C. Engines /RK Rajput/Laxmi Publications

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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	
ME9073	Biofluid Mechanics	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Fluid Mechanics, Thermodynamics and Heat Transfer in B.Tech/BE Course		CT+EA					
Course Outcomes	CO1: Students will be able togain knowledge about basic principles of biotransport processes and the flow characteristics of various biological fluids CO2: Students will be able to study the pressure and flow patterns in blood vessels and the biofluid mechanics in human organs CO3: Students will be able toacquire an idea about flow and pressure measurement techniques in human body						

	Topics Covered	Hours
	Fundamentals of biotransport: Stress Tensor; Conservation of mass, momentum and energy; pulsatile flow in rigid and elastic tubes; Resistance, Compliance and Inertance; Concepts of two-Phase Flows; Classification of non-Newtonian Fluids; Non-Newtonian Fluid Flow in Human Body; Microscale Heat Transfer; Bioheat Transfer; Application of Magnetic Field in Hyperthermia	11
	Hematology and Blood Rheology: Components of blood, Blood Viscosity and Its Aspects, Rheological Models of Blood, Blood Diseases	4
	Circulatory Biofluid Mechanics: Macrocirculation System; Microcirculation System	7
	Interstitial andSynovial fluid flow	4
	Biofluid Mechanics of Organ Systems: Cardiovascular System;Respiratory System; Urinary System; The Liver	9
	Flow and pressure measurement techniques in human body: Indirect Pressure	5

	Measurements; Direct Pressure Measurement; Flow Measurement	
Text Books, and/or reference material	**Text Books:** 1. Biofluid Mechanics. Principles and Applications byA. Ostadfar 2. Nano and Bio Heat Transfer and Fluid Flow by M. Ghassemi and A. Shahidian 3. Biofluid Mechanics,An Introduction to Fluid Mechanics, Macrocirculation, and Microcirculation by Rubenstein et al. 4. Applied Biofluid Mechanics by L. Waite, J. Fine **Reference Books:** 1. Fluid Mechanics by F.M. White 2. Biofluid Dynamics Principles and Selected Applications by C. Kleinstreuer 3. Introductory Biomechanics - From Cells to Organisms by C.R. Ethier and C.A.Simmons	

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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	
ME9074	Microscale Transport Phenomena	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Undergraduate Fluid Mechanics, Engineering Thermodynamics, and Heat and Mass Transfer		CT+EA					
Course Outcomes	CO1:To learn the characteristics of microscale flows and heat transfer CO2:To learn various modelling approaches for transport in microchannel CO3: To applytheories of microscale physics in practical problems. CO4: To apply modelling approaches in microscale transport problems. CO5: To learn microfabrication processes and techniques for design CO6: To learn measurement techniques in microscale systems CO7: To design and analyze microscale systems for transport of heat, charge and Chemical species.						

	Topics Covered	**Hours**
	Introduction: Definition, Microscaledevices and systems, Applications.	2
	Scaling Analysis: Natural systems, Parallel plate capacitor for sensor, Micro droplets, Micro resonator, Micro reactor, Micro heat exchangers.	2
	Channel Flow: N-S equations, Dissipation effect, Compliance of channel wall.	3
	Transport Laws: Boundary slip, Momentum accommodation coefficients, Thermal accommodation coefficient, Slip flow, Molecular modelling.	4
	Diffusion, Dispersion and Mixing: Random walk model of diffusion, Stokes-Einstein Law, Fick's law, Fixed and constant planar source diffusions, Taylor dispersion, Micromixers, Soluble or rapidlyreacting wall,Reverse osmosis channel flow.	4
	Surface Tension Dominated Flows: Microscopic model of surface tension, Gibbs free energy, Young-Laplace equation, Contact angle, Wetting, Super hydrophobicity and hydrophilicity,Thermo-capillary flows, Diffuso-capillary	4

	flows, Electrowetting, Digital microfluidics, Marangoni convection and instability	
	Charged Species Flow: Electrical conductivity and charge transport, Electrohydrodynamic transport theory, Transport equation of dilute binary electrolyte, Electrolytic cell, Electric double layer or Debye sheath, Electro-kinetic phenomena, Electro-osmosis, Electro-osmotic micro-channel devices and systems, Electrophoresis, Dielectrophoresis.	4
	Magnetism and Microfluidics: Magnetophoresis, Magnetic sorting, Magnetic separation, Ferrofluidic pump, Heat transfer enhancement using ferrofluid, Magneto-hydrodynamics, MHD based microdevices	4
	Microscale Heat Conduction: Energy Carriers, Scale effects, Kinetic theory, Boltzmann transport theoryHeat transport in thin films and at solid-solid interfaces,Heat conduction in semiconductor devices, Laser heating.	4
	Microscale Convection: Scaling laws, Temperature jump boundary condition, Convection in parallel plate channel flow with and without viscous dissipation, Similarity and dimensionless parameters, Flow boiling in micro channels, Mini-channel versus micro-channel, Nucleate and convective boiling, Dryout incipience quality, Condensation heat transfer in mini-micro channels, Micro heat pipes.	4
	Micro Fabrication: Functional materials Lithography, Subtractive technique, Etching, Paterning, Deposition and growth, Additive techniques, Micrroforming, PDMS based molding, Bonding, Laser micro fabrication technique.	4
	Measurements Techniques: Measurements techniques formicroscale systems.	3
Text Books, and/or reference material	**Text Books:** 1. Introduction to Microfluidics, P. Tabeling, Oxford University Press, 2010. 2. Theoretical Microfluidics, H. Bruus, Oxford University Press, 2008. 3. Fundamentals and Applications of Microfluidic 3rd edition, N.T. Nguyen and S.T. Wereley, Artech House, 2019. 4. Transport Phenomena in Microfluidic Systems,Pradipta Kumar Panigrahi, Wiley,· 2016. **Reference Books:** 1. Micro- and Nanoscale Fluid Mechanics Transport in Microfluidic Devices, Brian J. Kirby, Cambridge Univ Press, 2010. 2. Nanofluidics and Microfluidics Systems and Applications,Shaurya Prakash, JunghoonYeom, Elsevier Science, 2014. 3. Physicochemical Hydrodynamics-An Introduction, Ronald F. Probstein, Howard Brenner, Elsevier Science, 2013. 4. Physicochemical Hydrodynamics, V. Levich, Prentice Hall, 1962.	

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	
ME9075	Solar Thermal Systems	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1. Understand the concept of various laws related to solar applications						

	CO2. To outline the basic idea of solar energy collection CO3. To outline the basic idea of solar energy storage. CO4. Develop capability to do basic design of solar thermal systems. CO5. Understand the economics of solar thermal systems.

Topics Covered	Hours
INTRODUCTION – Solar energy option, specialty and potential – Sun – Earth –Solar radiation, beam anddiffuse – measurement – estimation of average solarradiation on horizontal and tilted surfaces –problems – applications.	6
LIQUID FLATPLATE COLLECTORS –construction details – Capturing solar radiation – physical principles of collection – types – performance analysis – concentratingcollection – flat plate collectors, with planereflectors,evacuated collectors, cylindrical paraboliccollectors – Orientation and tracking – Performance analysis.	8
OTHER SOLAR DEVICES – Solar air heaters, solar stills, solar cookers, dryers, solar ponds; solar chimney, solar refrigeration, active and passiveheating systems.	8
THERMAL ENERGY STORAGE- Introduction – Need for – Methods of sensibleheat storage usingsolids and liquids – Packed bed storage – Latent heat storage –working principle – construction –application and limitations.	6
POWER GENERATION – solar central receiver system – Heliostats and Receiver– Heat transport system –solar distributed receiver system – Power cycles, workingfluids and prime movers, concentration ratio.	6
ECONOMICS- Principles of Economic Analysis – Discounted cash flow – Solarsystem – life cyclecosts – cost benefit analysis and optimization – cost basedanalysis of water heating systems.	8

Text books, and/ or reference material	**Text Books:** 1.Solar energy: Principles of Thermal Collection and Storage/ Sukhatme/TMH 2. Solar energy/ Garg/TMH **Reference Books** 1. Solar energy thermal processes/ Duffie and Beckman/John Wiley & Sons 2. Principles of solar engineering/ Kreith and Kreider/Taylor and Francis

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	
ME9076	Thermodynamics of Complex Systems	PEL	3	0	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 understand the history, concepts, formulations and applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in emerging areas of contemporary interest. CO2: Students will be able to analyze and solve various practical problems on

	applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in emerging areas. CO3: Students will be able to apply various analytical, semi-analytical, and physical solution techniques to industrial and theoretical problems in order to compare them with the results of CFD and experimentation.

	Topics Covered	Hours
	1. Magnetic Substances 1.1 Thermodynamic processes in magnetic substances 1.2 The magnetocaloric, magnetostrictive, and magnetoelastic effects 1.3 Adibatic demgnetization 1.4 Magnetocaloric power cycles	4
	2. Dielectrics 2.1 Thermodynamic processes in dieectrics 2.2 Pizoelectric, electrostrictive, electrocaloric, and pyroelectric effects 2.3 The thermodynamics of an electrical capacitor 2.4 The ferroelectric converter cycle	4
	3. Superconductivity 3.1 The thermodynamics of the transition from the superconducting to the normal state 3.2 Phase diagrams for superconductors 3.3 The heat capacities of the superconducting and normal phases: Rutger eqution 3.4 Magnetostriction in superconductors	4
	4. Surface Phenomena 4.1 Special properties of an interfacial surface 4.2 Surface tension 4.3 The influence of surface phenomena on thermodynamic properties 4.4 Capillarity	4
	5. Fluids in Gravitational Field 5.1 The basic thermodynamic relations for systems in a gravitational field 5.2 The entropy of a system in a gravitational field 5.3 Adiabatic flow in a gravitational field 5.4 The thermodynamics of the atmosphere	4
	6. Liquid in a Vessel in Weigtlessness 6.1 A two-phase system in weightlessness 6.2 The possibility of phase separation from the vessel walls 6.3 Stable equilibrium in two-phase system	3
	7. Radiation 7.1 Equation of a state of a photon gas 7.2 The entropy and chemical potential of a photon gas 7.3 Thermodynamic processes in a photon gas: Heat capacity	3
	8. Elastic Solids 8.1 The caloric properties of an elastically deformed rod 8.2 The thermodynamic processes of rod deformation 8.3 The elastocaloric effect 8.4 Accounting for the change in volume of a solid under stress	4
	9. Voltaic Cells 9.1 Gibbs-Helmholtz equations 9.2 The basic thermodynamic relations for a voltaic cell: The Helmholtz eqution 9.3 Thermodynamic processes in a voltaic cell	3
Text Books, and/or reference	**Text Books:** 1. V. V. Sychev, Complex Thermodynamic Systems (Translated: E. Yankovsky), Mir, 1981. 2. J. L. Ericksen, Introduction to the Thermodynamics of Solids, Springer, 1998. 3. D. R. Gaskell, Introduction to the Thermodynamics of Materials, Taylor & Francis, 2008.	

material	**Reference Books:** 1. R. Kh. Dadashev, Thermodynamics of Surface Phenomena, Cambridge, 2009. 2. P. Glansdorff, I. Prigogine, Thermodynamic Theory of Structure, Stability and Fluctuations, Wiley-Interscience, 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	
ME9077	Advanced Refrigeration and Air-conditioning	PEL	3	0	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 understand the history, concepts, formulations and applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in Cold Production. CO2: Students will be able to analyze and solve various practical problems on applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in Refrigeration and Air-Conditioning. CO3: Students will be able to apply various graphical techniques to solve industrial and theoretical problems.					

	Topics Covered	Hours
	Actual vapor compression system - Multipressurevapour 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 psychrometric 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
Text Books, and/or reference material	**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. **Reference Books:** 1. Manohar Prasad, Refrigeration and Air Conditioning, New Age International, 1996. 2.Gosney, W.B., Principles of Refrigeration, Cambridge Uni. Press, 1982.	

<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>ME9078</td><td>Design of Thermal Systems</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT+EA</td></tr>
<tr><td colspan="3">Course Outcomes</td><td colspan="5">CO1: Students will be able to understand the history, concepts, formulations and applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in the Design principle of especially thermal systems.
CO2: Students will be able to analyze and solve various practical problems on applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in Thermal Design.
CO3: Students will be able to apply various economic considerations to address industrial problems.</td></tr>
<tr><td rowspan="4"></td><td colspan="6">Topics Covered</td><td>Hours</td></tr>
<tr><td colspan="6">Modelling of Thermal Systems: types of models, mathematical modelling, curve fitting, linear algebraic systems, numerical model for a system, system simulation, methods for numerical simulation;</td><td>8</td></tr>
<tr><td colspan="6">Acceptable Design of a Thermal System: initial design, design strategies, design of systems from different application areas, additional considerations for large practical systems; Economic Considerations: calculation of interest, worth of money as a function of time, series of payments, raising capital, taxes, economic factor in design, application to thermal systems;</td><td>15</td></tr>
<tr><td colspan="6">Problem Formulation for Optimization: optimization methods, optimization of thermal systems, practical aspects in optimal design, Lagrange multipliers, optimization of constrained and unconstrained problems, applicability to thermal systems; search methods: single-variable problem, multivariable constrained optimization, examples of thermal systems; geometric, linear, and dynamic programming and other methods for optimization, knowledge-based design and additional considerations, professional ethics.</td><td>17</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. W.F. Stoecker, Design of Thermal Systems - McGraw-Hill, 1971
2. N.V. Suryanarayana, Design & Simulation of Thermal Systems - MGH, 2002.
Reference Books:
1. Y. Jaluria, Design and Optimization of Thermal Systems –CRC Press, 2007.
2. Bejan, G. Tsatsaronis, M.J. Moran, Thermal Design and Optimization - Wiley, 1996.</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>ME9079</td><td>Heat Transfer Equipment Design</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</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">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td colspan="2">Course Outcomes</td><td colspan="6">CO1: Students will be able to understand the history, concepts, formulations and applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in the design principle of various Heat Transfer Equipments.

CO2: Students will be able to analyze and solve various practical problems on applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in designing Heat Transfer Equipments.

CO3: Students will be able to apply various analytical and numerical techniques to solve industrial and theoretical problems.</td></tr>
<tr><td rowspan="6"></td><td colspan="6">Topics Covered</td><td>Hours</td></tr>
<tr><td colspan="6">Constructional Details: Types, Fluid flow arrangements, parallel, counter and cross flow, shell and tube heat exchanger, Regenerators and recuperator, Condensers – Industrial applications;</td><td>6</td></tr>
<tr><td colspan="6">Heat Transfer: Modes of Heat Transfer, Overall heat transfer coefficient, Thermal resistance, Efficiency. Temperature Distribution and its implications, LMTD, effectiveness;</td><td>6</td></tr>
<tr><td colspan="6">Flow Distribution: Effect of Turbulence, Friction Factor, Pressure Loss, Orifice, Flow nozzle, Diffusers, Bends, Baffles, Effect of Channei Divergence, Manifolds;</td><td>8</td></tr>
<tr><td colspan="6">Stress in tubes, Headers sets and Pressure vessels: Differential Thermal Expansion, Thermal stresses, Shear stresses, Thermal sleeves, Vibration, Noise, types of failures. ;</td><td>10</td></tr>
<tr><td colspan="6">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.</td><td>10</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">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.</td></tr>
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Department of Mechanical Engineering

Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)$^{\#}$	Total Hours	
ME9080	Design with Constructal Law	PEL	3	0	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 understand the history, concepts, formulations and applications of Thermodynamics, Heat Transfer, and Fluid Mechanics in Thermal System Analysis. System analysis is a predominant part in every branch of engineering. It paves the way for system design, system simulation and finally the manufacturing. 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, semi-analytical, and physical solution techniques to industrial and theoretical problems in order to compare them with the results of CFD and experimentation.

Topics Covered	**Hours**
1. Flow system analysis: Heat and fluid flow 1.1 Vascularization, and sveltness 1.2 Fluid flow system analysis in general 1.3 Heat transfer system analysis in general 1.4 Examples with applied industrial problems	3
2. Distribution of imperfections: Second law based approach 2.1 Evolution towards the least imperfect possible 2.2 Imperfection due to heat transfer and fluid flow 2.3 Analysis of industrially important engineering components 2.4 Examples with applied industrial problems	3
3. Analysis of simple flow configurations 3.1 Flow of heat and fluid between two points: Fermat type flow 3.2 Internal spacing design 3.3 Competing extremes: Method of intersecting asymptotes 3.4 Evolution of technology from natural to forced convection	3
4. Tree networks for fluid flow and heat transfer 4.1 Performance versus freedom to morph 4.2 Strategies for faster design 4.3 Loop, junction, and fractal-like trees 4.4 Examples of asymmetry in some industrial problems	3
5. Configurations for heat conduction 5.1 Trees at micro and nanoscales 5.2 Conduction trees with loops 5.3 Trees for cooling disk-shaped body 5.4 Evolution of technology from forced convection to solid-body conduction	3
6. Multiscale configurations 6.1 Multiscale droplets for maximum mass transfer density	3

	6.2 Multiscale cylinders in crossflow 6.3 Heat transfer rate density: the smallest scale 6.4 Distribution of heat sources for some industrial problem	
	7. Multiobjective configurations 7.1 Thermal resistance versus pumping power 7.2 Complex flow structures are robust 7.3 Contemporary heat exchanger technology 7.4 Tree-shaped insulation design for distribution of hot water	3
	8. Vascularized materials 8.1 Vascularization: Natural design rediscovered 8.2 Self-healing materials 8.3 Counterflow line-to-line trees 8.4 Illustrations with industrially important problems	3
	9. Configurations for mass transfer 9.1 Scaling analysis of transport through porous media 9.2 Electrokinetic transport for biological systems 9.3 Migration through finite porous medium 9.4 Chosen applications to industrially important problems	3
	10. Mechanical and flow structures combined 10.1 Optimal flow of stresses 10.2 Mechanical structure resistant to thermal attack 10.3 Analogical study with vegetation 10.4 Case study with selected industrially important problems	3
	11. Structure in Time: Rhythm 11.1 Intermittent heat transfer 11.2 Defrosting refrigerators 11.3 Cleaning power plants 11.4 Applications to biologically inspired industrial systems	3
Text Books, and/or reference material	**Text Books:** 1. A. Bejan, S. Lorente, Design with Constructal Theory, Wiley, 2008. 2. A. Bejan, I. Dincer, S. Lorente, A. Miguel, H. Reis, Porous and Complex Flow Structures in Modern Technologies, Springer, 2011. 3. A. Bejan, Shape and Structure, from Engineering to Nature, Cambridge, 2000. **Reference Books:** 1. A. Bejan, J. P. Zane, Design in Nature, Anchor Books, 2013. 2. A. Bejan, Entropy Generation Through Heat and Fluid Flow, Wiley, 1982.	

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	
ME9081	Analysis of Thermal Power Cycles	PEL	3	0	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 understand the history, concepts, formulations and applications of Thermodynamics in Power producing Cycles.					

	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 techniques to solve industrial and theoretical problems.	
	Topics Covered	**Hours**
	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 - Regeneration - Inter cooling and reheating between stages.	6
	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.	

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	
ME1051	Heat Transfer Laboratory	PCR	0	0	4	4	2
Course Outcomes	CO1: Acquire an idea about conduction transport mechanism. CO2: To learn the basics of convection transfer. CO3: To learn the basic knowledge about radiation heat transfer.						
	Experiments Covered						
	Linear Heat conduction						
	Forced Convection						
	Radiation						
	Boiler						

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	
ME1052	Computational Laboratory	PCR	1	0	4	5	3
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.						
	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						

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	
ME2051	Thermal Engineering Laboratory	PCR	0	0	4	4	2
Course Outcomes	CO1: To learn the fundamentals of experimental techniques. CO3: To perform experimental validation of theory in heat transfer and experimental modelling. CO2: To learn the design and analysis of experiments.						
	Experiments Covered						
	Radial Heat conduction						
	Diesel Engine trial run						
	Fluidization and Fluidized Bed Heat Transfer						
	Morse Test						

Department of Mechanical Engineering							
ME2072	Mini Project with Seminar	PCR	0	0	0	6	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA)					
NA		CT+EA					
Course Outcomes	CO1: To be able to conduct review of literature to arrive at selected advanced topic for project work. CO2: Ability to interpret ideas and thoughts into practice in a project. CO3: Ability to analyze the gap between theoretical and practical knowledge. CO4: To be able to write and present a technical report with suitable conclusion as per international standards CO5: To be able to discuss and depend the outcome of the report in a seminar						
Topics Covered	Project as decided based on literature survey with consultation with the supervisor						

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME3071	DISSERTATION - I	PCR	0	0	24	24	12
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1: Ability to interpret ideas and thoughts into practice in a project. CO2: Ability to analyze the gap between theoretical and practical knowledge. CO3: Ability to compose technical presentation in the conferences. CO4: Ability to prepare for publishing papers in journals. CO5: Ability to propose for the patent rights for the projects.						
Topics Covered	Project as decided based on literature survey with consultation with the supervisor						

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME3072	Seminar (Non- Project)	PCR	**0**	**0**	**4**	**4**	**2**
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1: To be able to conduct review of literature to arrive at selected advanced topic for seminar. CO2: To be able to summaries the concept of the chosen topic systematically after considerable study of the content from primary as well as secondary sources CO3: To be able to write and present a technical report with suitable conclusion as per international standards CO4: To be able to discuss and depend the outcome of the report in a seminar						
Topics Covered	Topics decided by consultation with the supervisor						

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME4071	DISSERTATION - II / INDUSTRIAL PROJECT	PCR	0	0	24	24	12
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1: Ability to interpret ideas and thoughts into practice in a project. CO2: Ability to analyze the gap between theoretical and practical knowledge. CO3: Ability to compose technical presentation in the conferences. CO4: Ability to prepare for publishing papers in journals. CO5: Ability to propose for the patent rights for the projects.						
Topics Covered	Project as decided based on literature survey with consultation with the supervisor						

Department of Mechanical Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
ME4072	Project Seminar	PCR	0	0	4	4	2
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NA		CT+EA					
Course Outcomes	CO1: Ability to assess knowledge in the subject and the project. CO2: Ability to integrate technical question through all the years of study. CO3: Ability to express and communicate.						

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