Department: Mechanical Engineering

Programme: M. Tech. in Mechanical Engineering

Learning Outcomes based Curriculum

Preamble

In a learning outcome-based teaching pedagogy, the demonstrated achievement of outcomes in terms of knowledge, understanding, skills, attitudes, and the academic standard of the graduates is a key concern. Designing the programme outcomes (POs) for a particular post graduate (PG) programme, based on what a postgraduate in Mechanical Engineering is expected to know, understand and able to do at the end of the study programme is undoubtedly an important aspect. The expected POs are also crucial reference points in the sense that these assist in formulating graduate attributes, qualification descriptors, programme learning outcomes and course outcomes etc. Proper formulation of the above also helps in curriculum planning and development, and also in the design, delivery and review of academic programmes. The two years M. Tech. programme in Mechanical Engineering has been designed taking into consideration the above factors so that all the attributes of a learning outcome based curriculum is met. Additionally, inputs from statutory bodies such as AICTE, NAAC and NBA, along with inputs from stake holders are also taken in consideration before formulating the curriculum.

1. Introduction

The M. Tech. programme in Mechanical Engineering is offered with the following Programme Educational Objectives (PEOs).

1. Impart knowledge on advanced topics of Mechanical Engineering.
2. Practice engineering knowledge, critical thinking and real life problem solving.
3. Pursue research and develop creative and innovative ideas in Mechanical Engineering and other interdisciplinary areas.
4. Prepare students for higher learning and successful career in academia, industry and the government sector.
5. Inculcate in students the sense of responsibility, professionalism, ethics and leadership.

2. **Qualification descriptors for the graduates**

(i) **Knowledge & Understanding** (maximum 3)

- Demonstrate a dedicated understanding in field of specialization in mechanical engineering,its different learning areas and applications, and its linkages with related disciplinary areas/subjects;
- Demonstrate procedural knowledge that creates different types of professionals related to the specialized domain of mechanical engineering, including research and development, teaching and academics and also the industrial sector.
- Demonstrate comprehensive knowledge about the domain of specialization, including research, relating to essential learning areas pertaining to mechanical

engineering. Also develop techniques and skills required for identifying problems and issues relating to the specialized field of study.

(ii) Skills & Techniques (Maximum 3)

- Demonstrate skills in areas related to specialization in mechanical engineering and be up to date on the current developments in the field of specialization.
- Demonstrate skills related to the specialization in mechanical engineering which are transferable and relevant/requiredforjobs in industrial sectors and employment opportunities.
- Apply one's knowledge on the specialization in mechanical engineering and transferable skills to new/unfamiliar contexts, to identify andanalyseproblems and issues and solve complex problems with well-definedsolutions.

(iii) Competence (Maximum 3)

- Meet one's own learning needs, drawing on a range of current research and development work and professional materials;
- Communicate the results of studies undertaken in an academic field accurately in a range of different contexts using the main concepts, constructs and techniques of the subject(s)
- Demonstrate competence in identifying information needs, collection of relevant quantitative/qualitative data, analysis and interpretation of data using methodologies as appropriate to the subject(s) for formulating evidence-based solutions and arguments.

3. **Graduates Attributes**
   - Scholarship of knowledge
   - Critical thinking
   - Problem solving
   - Research skill
   - Modern tool usage
   - Collaborative and multidisciplinary work
   - Project management
   - Communication
   - Life-long learning
   - Ethical practices and social responsibility
   - Independent and reflective learning

4. **Program Outcomes:** The students from this program will attain:
   1. An ability to independently carry out research /investigation and development work to solve practical problems.
   2. An ability to write and present a substantial technical report/document.
   3. An ability to demonstrate a degree of mastery and in-depth knowledge in the following specialized areas:
      a. Numerical and experimental fluid flow and heat transfer
      b. Design, analysis and optimization of Mechanical systems
      c. Materials engineering for design
      d. Renewable thermal energy

5. PROGRAMME STRUCTURE

Currently, the M. Tech. in Mechanical Engineering is being offered in two specializations viz. Thermal and Fluids Engineering and Machine Design. Detail course structure of the Thermal and Fluids Engineering spcializations is given below.

Structure of the M. Tech. curriculum (Specialization: Thermal and Fluid Engineering)

Total Credits: 66

	Course Category	Course Detail								Category-wise credits
		SN	Code	Title	L	T	P	Cr	CH	
I	Core courses	1	ME-535	Advanced Engg. Thermodynamics	3	0	0	3	3	45
		2	ME-541	Advanced Fluid Mechanics	3	1	0	4	4	
		3	ME-562	Experimental Methods in Thermal and Fluid Engineering	3	0	2	7	5	
		4	ME-530	Numerical methods	3	0	1	5	4	
		5	ME-548	Convective Heat and Mass transfer	3	0	0	3	3	
		6	ME-593	Seminar	0	0	0	4	2	
		7	ME-611	MTech Thesis part I					12	
		8	ME-612	MTech Thesis part II					12	
II	Elective courses	1	xx-xxx	Open Elective I					3	21
		2	xx-xxx	Elective I					3*	
		3	xx-xxx	Elective II					3*	
		4	xx-xxx	Open Elective II					3	
		5	xx-xxx	Elective III					3	
		6	xx-xxx	Elective IV					3*	
		7	xx-xxx	Elective V					3*	
									Total credits	**66**

6. SEMESTER-WISE SCHEDULE

Specialization: Thermal and Fluid Engineering

Semester	Course detail								Total Credits
	SN	Code	Title	L	T	P	CH	Cr	
I	1	ME-535	Advanced Engg. Thermodynamics	3	0	0	3	3	21
	2	ME-541	Advanced Fluid Mechanics	3	1	0	4	4	
	3	ME-562	Experimental Methods in Thermal and Fluid Engineering	3	0	2	7	5	

	4	xx-xxx	Open Elective I					3	
	5	xx-xxx	Elective I					3*	
	6	xx-xxx	Elective II					3*	
II	1	ME-530	Numerical methods	3	0	1	5	4	21
	2	ME-548	Convective Heat and Mass transfer	3	0	0	3	3	
	3	xx-xxx	Open Elective II					3	
	4	xx-xxx	Elective III					3	
	5	xx-xxx	Elective IV					3*	
	6	xx-xxx	Elective V					3*	
	7	ME-593	Seminar	0	0	0	4	2	
III	1	ME-611	MTech Thesis part I					12	12
IV	1	ME-612	MTech Thesis part II					12	12
Total	**15**	**Minimum credit to be completed for award of the degree**							**66**

7. Mapping of courses with program outcomes (POs)

The M. Tech. Mechanical Engineering programme has three programme outcomes formulated in line with the graduate attributes of NBA. Similarly each course offered in various semesters also has certain course outcomes (COs). The COs of each and every course is linked with the POs in such a way that the strongest relation has the weight of 3 and the weakest relation is 1. Accordingly, the weight factor of the POs from the respective course is determined. The details regarding the CO PO linkage are attached below.

CO-PO mapping of M. Tech. Programme in Mechanical Engineering (Thermal and Fluid Engg.):

Course		PO1	PO2	PO3
ME535	CO1	2.5	1.5	2
	CO2	2.5	1.5	2.5
	CO3	2.5	1.5	3
	CO4	2.5	1.5	2
	CO5	2.5	1.5	2
	CO6	2.5	1.5	2.5
	CO7	3	1.5	3
ME541	CO1	1	×	3
	CO2	2	1	3
	CO3	2	1	3
	CO4	2	2	3
	CO5	2	×	3
	CO6	2	3	2
	CO7	2	1	3
ME562	CO1	2	×	2
	CO2	2	×	2
	CO3	3	×	3
	CO4	3	×	3
	CO5	3	×	3

Course		PO1	PO2	PO3
ME530	CO1	2	×	3
	CO2	2	×	3
	CO3	2	×	3
	CO4	2	×	3
	CO5	2	×	3
ME548	CO1	1	×	3
	CO2	3	1	3
	CO3	3	1	3
	CO4	3	2	3
	CO5	3	2	3
	CO6	1	2	1
ME593	CO1	1	×	3
	CO2	1	3	2
	CO3	1	1	2
	CO4	1	3	2
ME542	CO1	×	1	3
	CO2	×	1	3
	CO3	×	1	3
	CO4	×	1	3
	CO5	×	1	3
ME543	CO1	×	1	3
	CO2	×	1	3
	CO3	×	1	3
	CO4	×	1	3
	CO5	×	1	3
ME545	CO1	1	×	3
	CO2	2	1	3
	CO3	2	1	3
	CO4	2	2	1
	CO5	2	1	2
	CO6	2	1	3
ME547	CO1	2.5	1	2
	CO2	2.5	1	2.5
	CO3	2.5	2	3
	CO4	2.5	2	2.5
	CO5	2.5	2	2.5
	CO6	2	1	2
ME549	CO1	1	1	2
	CO2	2	1	3
	CO3	2	1	3
	CO4	2	2	2
	CO5	2	1	1
	CO6	2	1	3

Course		PO1	PO2	PO3
ME550	CO1	2.5	1.5	2.5
	CO2	3	1.5	2.5
	CO3	3	1.5	2.5
	CO4	3	1.5	2.5
ME551	CO1	3	3	2
	CO2	3	2	3
	CO3	2	2	3
	CO4	2	1	3
ME552	CO1	×	×	2
	CO2	×	×	2
	CO3	2	×	2
	CO4	3	×	3
	CO5	3	×	3
	CO6	2	2	3
	CO7	3	2	3
ME553	CO1	1	1	2
	CO2	2	1	3
	CO3	2	1	3
	CO4	2	2	2
	CO5	2	1	2
	CO6	×	×	×
ME603	CO1	2	1	3
	CO2	2	1	3
	CO3	2	1	3
	CO4	2	1	3
	CO5	3	1	3
	CO6	1	3	2
	CO7	1	3	2
ME611	CO1	2	×	3
	CO2	1	×	2
	CO3	3	×	2
	CO4	2	×	2
	CO5	1	×	2
	CO6	×	3	×
ME612	CO1	3	×	2
	CO2	1	2	3
	CO3	1	×	3
	CO4	1	×	3
	CO5	×	3	1
	CO6	×	3	×

8. **EVALUATION PLAN:**

The evaluation plan adopted is a continuous comprehensive evaluation system designed by the university as follows.

1. Sessional Test-I	25
2. Mid-sem examination	40
3. Sessional Test-II	25
4. End-sem Examination	60

The evaluation plan adopted is a continuous comprehensive evaluation system designed by the university. As a part of the evaluation plan, question papers are set with levels based on Bloom's taxonomy, with each question linked to the respective course outcomes. Subsequently, the attainment of course outcomes is assessed based on the students' performance in the test (marks attained by the students against questions linked to a particular course outcome).

9. **DETAILED SYLLABUS:** The detailed syllabus along with their credit structure is given in Annexure I.

Annexure I

M. Tech. Mechanical Engineering Syllabus
(Specialization: Thermal and Fluid Engineering)

ME-535: Advanced Engineering Thermodynamics L-T-P-CH-CR: 3-0-0-3-3

Review of first and second law of thermodynamics, Maxwell equations, Joule-Thompson experiment, irreversibility and availability, exergy analysis, phase transition, types of equilibrium and stability, multi-component and multi-phase systems, equations of state, chemical thermodynamics, combustion. Third law of thermodynamics.

Kinetic theory of gases- introduction, basic assumption, molecular flux, equation of state for an ideal gas, collisions with a moving wall, principle of equipartition of energy, classical theory of specific heat capacity.

Transport phenomena-intermolecular forces, The Van der Waals equation of state, collision cross section, mean free path

Statistical thermodynamics- introduction, energy states and energy levels, macro and microscales, thermodynamic probability, B-E, F-D, M-D statistics, distribution function, partition energy, statistical interpretation of entropy, application of statistics to gases-mono-atomic ideal gas, distribution of molecular velocity, ideal gas in a gravitational field.

Course outcomes:

CO1: Apply the Maxwell equations to derive the different thermodynamic property relations.
CO2: Apply the thermodynamic property relations for the physical explanation of the different thermodynamic phenomena.
CO3: Carry out exergy analysis of thermodynamic systems like steam and gas turbine power plants, vapour compression and vapour absorption refrigeration systems.
CO4: Carry out the thermodynamic stability analysis of multi-component and multi-phase systems and combustion.
CO5: Perform mathematical modeling and design of innovative thermodynamic systems.

Textbooks

1. Sears, F.W. and Salinger, G.L. *Thermodynamics, Kinetic Theory And Statistical thermodynamics,* Narosa Publishing House, New Delhi, 3rd ed., 1995.
2. Wylen, G.J.V and Sontag R.E. *Fundamentals of Classical Thermodynamics,* Wiley Eastern Limited, New Delhi, 1985.

Reference books

1. Moran, M.J. and Shapiro, H.N. *Fundamentals of Engineering Thermodynamics*, John Wiley and Sons, 6th ed., 2008.
2. Bejan, A. *Advanced Engineering Thermodynamics*, John Wiley and sons, 2006.

ME-541: Advanced Fluid Mechanics L-T-P-CH-CR: 3-1-0-4-4

Preliminary concepts on fluid, body force, surface force, scalar and vector fields, Eulerian and Lagrangian description of flow, motion of fluid element - translation, rotation and deformation.Vorticity and strain-rate tensors, integral and differential forms of governing equations - mass, momentum and energy conservation equations, stress tensor, principle of local stress equilibrium. Cauchy's equations of motion, transport theorems, constitutive equations, Stokes law of viscosity, Navier-Stokes equations, and their exact solutions, theory of hydrodynamic lubrication, flow between two concentric rotating cylinders. Stokes first and second problems, laminar boundary layer, Prandtl's boundary layer theory, similarity solution, momentum integral equation for boundary layer, Karman Pohlhausen approximation. Hydrodynamic stability - stability in elementary flow fields, introduction to turbulent flow, review of compressible flow - isentropic flow, flow with area change, flow with heat transfer, flow with friction, sonic flow, supersonic flow, shock waves, Prandtl Mayor's equation; Assignment and mini-project.

Course outcomes:

The contents, which are delivered in "Advanced Fluid Mechanics", are highly mathematical in nature.
On successful completion of this course, students will be able to -

CO1: Write the stress and strain rate tensors, constitutive equations and derive the governing equations of fluid flow in Cartesian and polar coordinates.
CO2: Solve, analayze and present the analytical solution of many complex laminar internal and external fluid flow problems in Cartesian and polar coordinate systems.
CO3: Solve, analyze and present the numerical solution of some complex laminar internal and external flow problems.
CO4: Present the physical concept of flow instability, leading to transition from laminar to turbulent flow.
CO5: Derive the Reynolds time averaged NS equations and turbulent stress components.
CO6: Present in details about the characteristic features of turbulent flow such as
  a. Fluctuations, eddies, mixing, statistical averaging, energy cascading etc.
  b. Linear stability theory, theoretical determination of critical Reynolds number.
  c. Prandtl mixing length hypothesis and the k-ε model of turbulence.
CO7: Solve, analyze and present some specific turbulent flow problems in internal and external flow geometries.

Textbooks

1. Muralidhar, K. and Biswas, G. *Advanced Engineering Fluid Mechanics*, Narosa Publishing House, New Delhi, 2005.
2. Graebel, W. *Advanced Fluid Dynamics,* Elsevier, Burlington, USA, 2007.

Reference books

1. Schlichting, H. *Boundary Layer Theory*, McGraw-Hill, 1979.
2. White, F.M. *Viscous Fluid Flow*, McGraw-Hill, New Delhi, 2011.
3. Munson, B.R., Young, D.F. and Okiishi, T.H. *Fundamental of Fluid Mechanics*, John Wiley & Sons, 2002.
4. Panton, R.L. *Incompressible Flow*, John Wiley & Sons, New Delhi, 2005.
5. Anderson, J.D. *Modern Compressible Flow with Historical Perspective*, McGraw-Hill, 1990.

ME-562: Experimental Methods in Thermal and Fluid Engineering L-T-P-CH-CR: 3-0-2-7-5

Theory and experimentation in engineering - problem solving approaches, types of engineering experiments, computer simulation and physical experimentation; Generalized measuring system, types of inputs, analog and digital signals, standards, calibration and uncertainty, measurement system - performance characteristics;

Analysis of experimental data, error analysis, uncertainty analysis, data reduction techniques, statistical analysis of data, probability distributions and curve fitting;

Thermometry - heat flux measurement – thermos-physical properties – Measurement of derived quantities - torque, power, radiation and surface properties.

Measurement of pressure, flow velocity measurement, wind tunnels and flow visualization, measurement of temperature, optical methods of measurements, hot wire anemometry, hot film anemometry, laser Doppler anemometer, instrumentation in two-phase flows, particle image velocimetry techniques.

Course outcomes:

CO1: Students will understand and apply knowledge on modern engineering experimentation, Including experiment design, calibration, data acquisition, analysis, and interpretation.
CO2: Students will be able to conduct experiments using real-world transducers / data acquisition system with specifications on resolution and accuracy.
CO3: Students will analyze the data using signal processing technique and uncertainty analysis for scientific and meaningful representation.
CO4: Students will be able to develop experimental setup through final year thesis work.
CO5: Students will be able to apply practical knowledge for carrying out future thermal engineering and heat transfer experimental and computational research.

Textboks

1. Holman, J. *Experimental Methods for Engineers* (McGraw-Hill, 2007)
2. Rathakrishnan, E. *Instrumentation, Measurements and Experiments in Fluids*, Taylor & Francis, New Delhi, 2017

Reference

1. Goldstein, R.J. *Fluid Mechanics Measurements* (Taylor & Francis, 1996).
2. Reddy T. A. *Applied Data Analysis and Modelling for Energy Engineers and Scientists*, Springer, London, 2011

ME-611: MTech Thesis Part I **L-T-P-CH-CR: 0-0-0-0-12**

Course-outcomes:

CO1: Demonstrate scholarly knowledge on the chosen research topic.
CO2: Formulate a complex and novel research problem.
CO3: Demonstrate the ability to acquire new skills and knowledge to analyze and model the chosen research problem.
CO4: Use modern tools and techniques to solve the problem and analyze the results.
CO5: Create innovative ideas and products to cater to address problems of societal need and industrial relevance.
CO6: Present the research findings in the form of a sound technical report.

ME-612: M Tech Thesis Part II **L-T-P-CH-CR: 0-0-0-0-12**

Course-outcomes:

CO1: Demonstrate the ability to solve complex and multidisciplinary research problems in a time-bound manner.
CO2: Critically assess, analyze, evaluate and present the research findings.
CO3: Create innovative ideas and products to cater to address problems of societal need and industrial relevance.
CO4: Identify scope for future research based on the thesis work.
CO5: Acquire the ability to independently write sound thesis and research papers.

CO6: Demonstrate good presentation skills.

ME-593: Seminar **L-T-P-CH-CR: 0-0-0-4-2**

In this course, students in consultation with specific faculty member will carry out literature survey in specific research area of interest and periodically present his/her observations in the form of seminar presentation. Finally, the student will submit a report on his/her observation. Based on the literature review conducted, students will choose their project and thesis works to be carried out in the second semester.

Course outcomes:

On successful completion of this seminar, the graduates will be able to

CO1: Understand thoroughly a particular topic at higher level
CO2: Acquire the art of presenting a selected topic of research systematically
CO3: Identify research problem to be carried out as a part of his/her final year thesis work.
CO4: Write a review on a particular research topic of his/her choice

ME-530: Numerical Method **L-T-P-CH-CR: 3-0-1-5-4**

Roots of single-variable nonlinear equations: Bracketing methods, bisection method, false position method, fixed point iteration, Netwon-Raphson method and secant method, solution of specific thermal engineering related problems using some of the above methods
Roots of singe-variable polynomials: Polynomial deflation, Bairstow's method and Muller method Numerical differentiation: Finite difference approximations of first and second order derivatives Numerical integration: Newton-Cotes Methods, Gauss quadrature
Linear system of equations**:** Direct Methods: Gauss elimination, Gauss-Jordan method, matrix inversion, LU decomposition
Iterative methods: Gauss-Seidel, Jacobi, Relaxation methods
Eigenvalues and eigenvectors**:** Direct power method, inverse power method and shifted power method
Similarity transformation: QR decomposition with Householder transformation Numerical solution of nonlinear equations: Fixed point iteration, Newton's method
Ordinary differential equations**:** Euler and Runge-Kutta methods for initial value problem, shooting and finite difference methods for boundary value problems, predictor-corrector method, eigenvalue problems, solution of boundary layer equations using Newton Raphson method and 4^{th} order Runge-kutta Method
Partial differential equations: Classification of PDEs and their characteristics, parabolic, elliptic and hyperbolic equations, Numerical solution of parabolic, elliptic and hyperbolic equations
Laboratory component: The laboratory component will include computer programming of the methods described and some other assignments through which students will be able to acquire the skill of writing computer programs/codes on numerical algorithms and solving real life problems related to thermal engineering.

Course-outcomes:

CO1: Find roots of single-variable transcendental and polynomial equations
CO2: Solve both linear and nonlinear systems of algebraic equations
CO3: Perform numerical differentiation and integration
CO4: Solve both ordinary and partial differential equations
CO5: Programming various numerical methods and apply them to different relevant real-

life problems

Textbooks:

1. Gerald, C.F. and Wheatley, P.O. *Applied Numerical Analysis*, Addison-Wesley, USA, 5th ed., 1994
2. Conte, S.D. and de Boor, C. *Elementary Numerical Analysis*, McGraw-Hill, 3rd ed., 2005.
3. Hildebrand, F.B. *Introduction to Numerical Analysis*, 2nd ed., Courier Dover Publications, New York, 1987.

Reference books:

1. Kreyszig, E. *Advanced Engineering Mathematics*, John Wiley & Sons, 10th ed., 2010.
2. Burden, R. L. and Faires, J. D. *Numerical Analysis*, Brooks/Cole, 9th ed., 2011.

ME-548: Convective heat and mass transfer **L-T-P-CH-CR: 3-0-0-3-3**

The field on convective heat transfer is a symbiosis between fluid dynamics and heat transfer. It deals with the complex nature of their interactions in different configurations. Simultaneous heat and mass transfer problems are also very common in applications such as moving boundary freezing and melting problems. This course aims to cover both the intermediate and advanced aspects of convective heat in more details and the basic preliminary ideas of convective mass transfer. The treatment of the course is highly mathematical; therefore, the students are expected to formulate and solve forced and natural convection heat transfer problems both analytically using advanced mathematical techniques and numerically in order to find out the convective heat transfer coefficient in different situations. As far as convective mass transfer is concerned, some basic preliminary ideas are given in correlating mass transfer with heat transfer. The course would benefit those students who are interested to pursue their research in a fluid flow and heat transfer areas.

Introduction: Introduction to forced and free convection, derivation of governing equations of momentum, energy and species transport, order of magnitude analysis, Reynolds analogy.

Convective heat transfer internal flows: Concept of hemodynamically developing and developed flows, thermally developing flows (Graetz problem) and thermally developed laminar flow, Overview of steady laminar forced convection in Hagen Poiseuille flow, Plane Poiseuille flow, and Couette flow, solutions of coupled momentum and energy equations in developing and fully developed flow and heat transfer problems with constant wall flux and constant wall temperature boundary conditions. Laminar developing and fully developed flow though non-circular ducts. Turbulence fundamentals and turbulent duct flow with forced convection.

Convective heat transfer in external flows: Derivation of hydrodynamic and thermal boundary layer equations, Similarity solution techniques, Momentum and energy integral methods and their applications in flow over flat plates with low and high Prandtl number approximations, Heat tranfer in turbulent boundary layers.

Free convection: Free convection boundary layer equations: order of magnitude analysis, similarity and series solutions, Concept of thermal stability and Rayleigh Benard convection, introduction to mixed convection, turbulent free convection.

Boiling and Condensation: Concept of boiling heat transfer and regimes in pool boiling, Homogeneous and heterogeneous nucleation, Nusselt film condensation theory, dropwise condensation and condensation inside tubes, effects of non-condensables, Deviations from continuum: wall slip and thermal creep, an introduction to convective transport in micro-scales

Mass transfer: Molecular diffusion in fluids, mass transfer coefficient, Simultaneous heat and mass transfer problems (moving boundary freezing and melting problems), introduction to convective mass transfer in binary systems, analytical solutions to simple one-dimensional problem.

Course outcomes:

The course contents of “**Convective Heat Transfer**” are highly mathematical in nature. On successful completion of this course, the graduates will be able to

CO1: Derive the general form of the energy equation using a specific coordinate system and generalized approach.

CO2: Solve, analyze and present steady and unsteady external and internal forced CHT problems with different boundary conditions.

CO3: Solve, analyze and present the GRAETZ problem of external and internal forced convection with different boundary conditions.

CO4: Solve, analyze and present forced and natural CHT problems using approximate technique.

CO5: Solve, analyze and present some specific CHT problems using numerical techniques.

CO6: Correlate CHT with convective mass transfer in terms of some specific dimensionless parameters and present their physical significance.

Text books

1. Kays, W. M., Crawford, E.M. and Bernhard W. *Convective Heat and Mass Transfer*, McGraw-Hill, 4th ed., 2004.
2. Bejan, A. *Convective Heat Transfer*, John Wiley and Sons, 4th ed., 2013.

Reference book

1. Burmeister, L. C. *Convective Heat Transfer*, John Wiley and Sons, 2nd ed., 1993.

ME 528: Energy Conservation and Waste Heat Recovery **L-T-P-CH-CR: 3-0-0-3-3**

Energy resources and use. Potential for energy conservation. Optimal utilization of fossil fuels. Total energy approach. Coupled cycles and combined plants. Cogeneration systems. Exergy analysis. Utilization of industrial waste heat. Properties of exhaust gas. Gas-to-gas, gas-to-liquid heat recovery systems. Recuperators and regenerators. Shell and tube heat exchangers. Spiral tube and plate heat exchangers. Waste heat boilers: various types and design aspects. Heat pipes: theory and applications in waste heat recovery. Prime movers: sources and uses of waste heat. Fluidized bed heat recovery systems. Utilization of waste heat in refrigeration, heating, ventilation and air conditioning systems. Thermoelectric system to recover waste heat. Heat pump for energy recovery. Heat recovery from incineration plants. Utilization of low grade reject heat from power plants. Need for energy storage: Thermal, electrical, magnetic and chemical storage systems. Thermo-economic optimization.

Course Outcomes:

At the completion of the course the student will be able to:

CO1: Understand the need of energy conservation

CO2: Identify the types of waste heat recovery systems and their components.

CO3: Identify problems associated with heat recovery systems

CO4: Apply their knowledge and understanding to analyse and design such systems as per requirements.

CO5: Student will be able to solve associated problems of waste heat recovery systems

Text books

1. Harlock, J.H. *Combined Heat and Power*, Pergaman Press, 1997.
2. Kreith, F. and West, R.E. *CRC handbook of Energy Efficiency,* CRC Press, 1997.

Reference book

1. Kays, W.M. and London, A.L. *Compact Heat Exchangers*, McGraw-Hill, New York, 1984.

ME-542: Computational Fluid Dynamics **L-T-P-CH-CR: 3-1-0-4-4**

Basic equations of fluid dynamics - general form of a conservation law, equation of mass conservation, conservation law of momentum, conservation equation of energy;
Dynamic levels of approximation - Navier-Stokes (NS) equation, Reynolds-averaged NS equations, thin layer and parabolised NS approximations, boundary layer approximation, Euler equations for inviscid rotational and potential flows, small disturbance approximation of potential flow, linearized potential flow, nature of PDE and flow equations;
Basic discretization techniques - explicit and compact schemes for spatial discretization, central and upwind schemes; Integration of system of ODEs - explicit and implicit methods, multi-step methods, predictor-corrector schemes, ADI methods, Runge-Kutta schemes;
Analysis and application of numerical schemes – consistency, stability, convergence, von Neumann stability analysis, modified equation, application of finite difference method to wave, heat, Laplace and Burgers equations; Linear solver - error and convergence properties of $Ax=b$ as encountered in CFD, successive over-relaxation, ILU factorization;
Finite volume methods - finite volume discretization of time derivative, convective term and dissipative term;
Numerical solution of Euler equations - formulation of system of Euler equations, space-centered schemes, upwind schemes, shock-tube problem, numerical solution of incompressible NS equations - streamline-vorticity formulation, primitive variable formulation, staggered and collocated grids, pressure-correction algorithms, Lid-driven cavity flow;
Assignment and mini-project.

Course outcomes:

CO1: Obtain the finite difference approximations of partial derivatives to specified orders of accuracy.
CO2: Discretize the governing equations of fluid mechanics and heat transfer on finite difference and finite volume frameworks.
CO3: Carry out linear stability analysis of various numerical schemes for solving PDEs governing fluid flow and heat transfer.
CO4: Solve a system of discrete linear algebraic equations using iterative solvers.
CO5: Write computer codes to solve basic fluid flow and heat transfer problems using numerical methods and use appropriate post-processing methods for analyzing the solutions.
CO6: Identify the challenges and scopes of further research in the field of computational fluid dynamics.

Textbooks

1. Anderson, J.D. *Computational Fluid Dynamics*. McGraw-Hill, 1995.
2. Ferziger, J.H. and Peric, M. *Computational Methods for Fluid Dynamics*, Springer, 2002.

References

1. Pletcher, R., Tannehill, J.C. and Anderson, D. *Computational Fluid Mechanics and Heat Transfer,* Taylor & Francis, 2011.
2. Versteeg, H.K. and Malalasekera, W. *An Introduction to Computational Fluid Dynamics: The Finite Volume Method,* Longman, 1995.
3. Patankar, S.V. *Numerical Heat Transfer and Fluid Flow* , Hemisphere, 1980.
4. Hirsch, C. *Numerical Computation of Internal and External Flows*, Vol. 1 and 2, John Wiley & Sons,

1990.

ME-543: Compressible Flow **L-T-P-CH-CR: 3-1-0-4-4**

Review of thermodynamics and fluid mechanics, integral forms of conservation equations, differential conservation equations, Crocco's theorem, speed of sound and Mach number;
Basic equations for one dimensional flows, isentropic relations, normal shock wave, Rankine- Hugoniot relations, Fanno and Rayleigh curves, Mach waves, oblique shock wave, attached and detached shock waves, shock polar, shock interaction and reflection;
Linearized subsonic flow, linearized supersonic flow, small perturbation theory, Prandtl-Meyer expansion waves, method of characteristics;
Quasi-one-dimensional flows – governing equations, area-velocity relations, isentropic flow through variable area ducts, convergent-divergent nozzles, over-expanded and under-expanded nozzles, diffusers;
Unsteady wave motion – moving normal shock waves, reflected shock waves, physical features of wave propagation, elements of acoustic theory, incident and reflected shock waves, shock tube relations, incident and reflected expansion waves, finite compression waves;
Hypersonic gas dynamics – general characteristics of hypersonic flow, hypersonic shock and expansion relations, similarity parameters, determination of surface pressure distribution in hypersonic flow field, hypersonic boundary layer;
Aero-test facilities – closed and open circuit wind tunnels, supersonic wind tunnels, shock tunnels, impulse facilities, hypersonic wind tunnels, shock tunnels; Assignment and mini-project.

Course-outcomes:

CO1: Use the governing equations for one-dimensional compressible flow to find the density, pressure and velocity profiles along the flow.
CO2: Calculate the property changes across normal and oblique shock waves.
CO3: Solve and analyze problems on one-dimensional adiabatic flow with friction, and one-dimensional frictionless flow with heat transfer.
CO4: Analyze complex phenomena of compressible flows including shock reflections, shock- shock interactions, and Pradtl-Meyer expansions.
CO5: Analyze quasi one-dimensional flow through a converging-diverging nozzle.
CO6: Analyze hypersonic flow involving shock-shock as well as shock-wave boundary layer interactions.

Textbooks

1. Anderson, J.D. *Modern Compressible Flow with Historical Perspective*, McGraw-Hill, 1990.
2. Liepmann, H.W. and Roshko, A. *Elements of Gas Dynamics,* Dover, 2007.

References

1. Shapiro, A. *The Dynamics and Thermodynamics of Compressible Flow*, Ronald Press, 1950.
2. Anderson, J.D. *Hypersonic and High Temperature Gas Dynamics*, McGraw-Hill, 1990.
3. Barlow, J.B, Rae, W.H. and Pope, A. *Low Speed Wind Tunnel Testing*, John Wiley & Sons, 1999.
4. Pope, A. and Kennith, L.G. *High Speed Wind Tunnel Testing*, John Wiley & Sons, 1965.
5. Lukasiewicz, J. *Experimental Methods of Hypersonic* , Mercel Dekker, 1973.

ME-544: Turbulent Shear Flow **L-T-P-CH-CR: 3-0-0-3-3**

Nature of turbulent flows, equations of fluid motion – continuity, momentum, conserved passive scalars;
Statistical description of turbulent flows – random nature of turbulence, characteristics of random variables,

joint random variables, normal and joint-normal distribution;
Mean flow equations – Reynolds equations, Reynolds stresses, mean scalar equation, gradient- diffusion and turbulent-viscosity hypothesis;
Free shear flows – round jet, self-similarity, kinetic energy, other self-similar flows – plane jet, plane mixing layer, plane wake, axisymmetric wake;
Scales of turbulent motion – energy cascade, Kolmogorov hypothesis, energy spectrum, two-point correlation, Fourier modes, velocity spectra;
Wall flows – pipe flow, boundary layers, turbulent structures, direct numerical simulation; Turbulent viscosity models – mixing-length model, turbulent-kinetic energy models, k-ε model; Assignment and mini-project.

Course outcomes:

Towards the end of the course the student would be able to

CO1: Apply the knowledge of statistical description of turbulent flows to analyze the random characteristics of turbulent flows.
CO2: Analyze the turbulent free shear flows in various jets, layers, wakes etc. and find out their self-similar solutions.
CO3: Apply Kolmogorov theory to formulate the energy spectrum and various scales in turbulent flows.
CO4: Perform the simulation of turbulent wall bounded flows such as development of boundary layer in pipe and channel flows.
CO5: Apply the various turbulent viscosity models such as mixing-length model, turbulent-kinetic energy models, k-ε model in analyzing turbulent flow problems.
CO6: Perform state-of-the-art literature survey in the field of turbulent shear flows and present in the form of technical reports and seminars.

Textbooks

1. Townsend, A.A.R. *The Structure of Turbulent Shear Flow*, Cambridge University Press, 1980.
2. Pope, S.B. *Turbulent Flows,* Cambridge University Press, 2000.

References

1. Hinze, J.O. *Turbulence*, McGraw-Hill, 1975.
2. Schlichting, H. and Gersten, K. *Boundary-Layer Theory*, Springer, 2000.
3. Tennekes, H. and Lumley, J.L. *A First Course in Turbulence*, MIT Press, 1972.

ME-545: Viscous Fluid Flow **L-T-P-CH-CR: 3-0-0-3- 3**

Preliminary concepts, conservation of mass, momentum and energy;
Stokes law of viscosity and Navier-Stokes equations, governing equations of fluid motion in cylindrical-polar coordinates;
Exact solutions of the viscous flow equations - shear-driven (Couette) flows, pressure-driven (Poiseuille) flows, plane Couette-Poiseuille flows, plane stagnation-point flow, Stokes' first problem and similarity solution, Stokes' second problem;
Laminar boundary-layers - Prandtl's boundary-layer theory, boundary layers over flat plate and wedge, similarity solutions, integral analysis, one-parameter integral method, Karman-Pohlhausen approximation, correlation method of Thwaites, boundary-layer flow over a circular cylinder;
Laminar free-shear flows - jet, wake and mixing layer; Stability of laminar flows - Orr-Sommerfeld equation, Rayleigh's equation, indifference curves, stability analysis, laminar-turbulent transition;
Turbulent flow - fundamentals, Reynolds-averaged equations, boundary-layer equations, energy budget of turbulent fluctuations, structure of turbulent boundary-layer, law of the wall;

Assignment and mini-project.

Course outcomes:

On successful completion of this course, the graduates will be able to

CO1: Write governing equations in vector as well as in expanded form for Cartesian and polar coordinate systems.

CO2: Solve, analyze and present the analytical solution of a number of laminar internal and external fluid flow problems in Cartesian and polar coordinate systems.

CO3: Solve, analyze and present the numerical solution of some complex laminar internal and external flow problems.

CO4: Present the physical concept of flow instability, leading to transition from laminar to turbulent flow

CO5: Derive the Reynolds time averaged NS equations and turbulent stress components.

CO6: Solve, analyze and present solution of some specific turbulent flow problems in internal and external flow geometries.

Textbooks

1. White, F.M. *Viscous Fluid Flow*, Tata McGraw Hill, 2011.
2. Papanastasiou, T.C., Georgiou, G.C. and Alexandrou, A.N. *Viscous Fluid Flow* , CRC Press, 2000.

References

1. Ockendon, H. and Ockendon, J.R. *Viscous Flow,* Cambridge University Press, 1995.
2. Zeytounian, R.K. *Theory and Applications of Viscous Fluid Fflow*, Springer, 2004.
3. Zeytounian, R.K. *Asymptotic Modeling of Atmospheric Flows,* Springer-Verlag, 1990.
4. Joseph, D.D. *Stability of Fluid Motions, Vol. 2* , Springer-Verlag, 1976.
5. Telionis, D.P. *Unsteady Viscous Flows* , Springer-Verlag, 1981.
6. Shankar, P.N. *Slow Viscous Flows*, World scientific, 2007.

ME-546: Fluid Transportation Systems **L-T-P-CH-CR: 3-0-0-3- 3**

Basic concepts in fluid mechanics, transport theorems, integral conservation principles, constitutive equations;

Differential conservation principles;

Dimensional analysis - theory and applications, dimensionless equations and numbers;

Transport phenomena at interfaces, introduction to boundary layer, momentum, heat and mass transport;

Fundamentals of two-phase flow, phase separation and settling behavior, slurry pipeline transportation;

Design methods, pneumatic conveying; Assignment and mini-project.

Textbooks

1. Hauke, G. *An Introduction to Fluid Mechanics and Transport Phenomena*, Series: Fluid Mechanics and Its Applications, Vol. 86 (Springer, 2008)

References

1. Deen, W.M. *Analysis of Transport Phenomena* (Oxford University Press, 1998)
2. Bird, R.B., Stewart, W.E. and Lightfoot, E.N. *Transport Phenomena* (Wiley, 2005)
3. Hershey, H.C. and Brodkey, R.S. *Transport Phenomena: A Unified Approach*, Vol. 1 & 2 (Brodkey

Publishing, 2003)

ME-547: Two Phase Flow **L-T-P-CH-CR: 3-0-0-3- 3**

Introduction, hydrodynamics of gas-liquid flow - homogeneous, separated and drift-flux models; Flow pattern maps, stratified, bubbly, slug and annular flows, bubble formation and dynamics; Principles and applications of pneumatic transport;
Hydrodynamics of solid-liquid flow, design equations for hydrodynamic transportation, nucleate and film boiling, flow boiling, enhancement of boiling heat transfer coefficient, film and drop-wise condensation; Experimental methods for boiling and two-phase flow; Assignment and mini-project.

Course outcomes:

Towards the end of the course the student would be able to

CO1: Apply the hydrodynamics of two phase flow such as gas-liquid in homogeneous, separated and drift-flux modeling.
CO2: Deal with multiphase flow problems by applying the knowledge of flow pattern maps involving stratified, bubbly, slug, annular flow etc.
CO3: Analyze, model and simulate the solid-liquid flow problem such as sedimentation.
CO4: Design and improve modeling of hydrodynamic and pneumatic transportation.
CO5: Analyze for improvement of heat transfer in boiling and condensation found in various practical situations.
CO6: Get experimental exposure on two phase flow, boiling and condensation.

Textbooks

1. Wallis, G.B. *One Dimensional Two-Phase Flows* (McGraw-Hill, 1969)
2. Brennen, C.E. *Fundamentals of Multiphase Flow* (Cambridge University Press, 2005)

References

1. Collier, J.B. and Thome, J.R. *Convective Boiling and Condensation* (Oxford Science Publications, 1994)
2. Ghiaasiaan, S.M. *Two-Phase Flow, Boiling and Condensation* (Cambrdige University Press, 2008)
3. Fan, L.S. *Principles of Gas Solid Flows* (Cambridge University Press, 1998)
4. Perker, S.M. and Helvaci, S.S. *Solid-Liquid Two-phase Flows* (Elsevier, 2008)

ME-549: Conduction and radiation heat transfer **L-T-P-CH-CR: 3-0-0-3-3**

Conduction: Derivation of energy equation for conduction in three dimensions – Initial and boundary conditions. Transient conduction- Concept of Biot number – Lumped capacitance formulation unsteady conduction from a semi-infinite solid-solution by similarity transformation method, Solution of the general 1D unsteady problem by separation of variables, integral methods of analysis for transient conduction, lumped and partially lumped capacitance methods, boundary value problems and orthogonal functions, Fourier and Chebyshev series, solution using separation of variables, semi-infinite and infinite domains, Duhamel's theorem, Laplace transforms, Green's functions, Solution of steady state 2D problem – solution by variable
separable method – concept of superposition and homogeneous boundary conditions.
Numerical solution of conduction problems: Basic ideas of finite difference method –forward, backward and central differences – Discretization for the unsteady heat equation. Solution of the 1D unsteady heat conduction equation
Radiation: Laws of thermal radiation. Radiation properties of surfaces, Concept of view factors,

Radiation exchange in black and diffuse grey enclosures, Radiation effects in temperature measurement, Enclosure theory for surfaces with wall temperatures that are continuous functions of space. Spectrally diffuse enclosure surfaces. Specularly reflecting surfaces

Radiation in participating media: The equation of radiative heat transfer in participating media; radiative properties of molecular gases and particulate media; exact solutions of one-dimensional grey media; Approximate solution methods for one-dimensional media (optically thin and optically thick approximations).

Concept of combined Conduction and Radiation with examples such as spacecraft radiator, solar radiation etc.

Course outcomes:

On successful completion of this course, students will be able to

CO1: Deal with transient heat conduction equation

CO2: Solve 1D unsteady problem with separation of variable method and integral method

CO3: Carry out calculations related to two-dimensional unsteady flow

CO4: Explain the background physics of the radiation heat transfer

CO5: Analyze radiation exchange in black and diffuse grey enclosures

CO6: Analyze radiative heat transfer in participating media.

Text Books:

1. F. P. Incropera, D. P. DeWitt, *Fundamental of Heat and Mass Transfer*, 5th Edition, John Wiley & Sons, Inc., 2016
2. D. Poulikakos, *Conduction Heat transfer*, Prentice Hall, 1994
3. M.N. Ozisik, *Heat Conduction*, 2nd edition, John Wiley & Sons, 1993
4. R. Siegel and J.R. Howell, *Thermal Radiation Heat Transfer*, Taylor and Francis, 2002

References:

1. G.E. Mayers, *Analytical methods in Conduction Heat Transfer*, McGraw Hill, 1971
2. V S Arpaci, *Conduction Heat Transfer*, Addison-Wesley, Reading, MA, 1966

ME-550: Heat Transfer Equipment Thermal Design **L-T-P-CH-CR: 3-0-0-3-3**

Basic consideration of design, Classification of heat transfer equipments - Design of shell and tube heat exchanger – Finned surface heat exchanger, enhanced heat transfer techniques –Heat exchangers for special services - Plate and spiral plate heat exchanger – plate heat exchanger for Dairy industry – Heat pipes, Acceptable design of thermal system and economic consideration, Thermal design of heat exchange equipments such as Air pre-heaters, Economizer – Super heater and condensers, Selection of compact heat exchangers, Analysis and design of cooling towers, optimization of thermal design.

Course outcomes:

CO1: Analyze the heat exchangers used in different purposes.

CO2: Design heat exchangers such as shell and tube, compact heat exchangers, condensers, evaporators considering the pressure drop, fouling etc.

CO3: Select the heat exchangers and their components based on operating parameters and quantity.

CO4: Perform the thermodynamic modeling of heat exchangers based on energy, exergy and cost analysis.

Text Books:

1. Bejan A., Tsatsaronis G., Moran, M. *Thermal Design and Optimization*, John Wiley & Son, Hoboken, 1996.
2. Kays, W.M. and London, A.L., *Compact Heat Exchangers*, McGraw-Hill, 1998

References:

1. Dunn, P. and Reay, D.A.*, Heat Pipes*, Pergamon, 1994
2. Kakac, S. and Liu, H., *Heat Exchangers*, CRC Press, 2002.
3. Ganapathy, V.*, Applied Heat Transfer*, Pennwell Books, 1982
4. Jaluria Y. *Design and Optimization of Thermal Systems*. 2nd Edition, Taylor & Francis Boca Raton (2008)

ME-551: Renewable Fluid Power Technology **L-T-P-CH-CR: 3-0-0-3-3**

Statistical analysis of wind regimes, dynamics of data acquisition, time distribution, frequency distribution and statistical modeling. Wind energy conversion principles: Types and classification of wind energy conversion system, power, torque, speed characteristics, maximum power co-efficient. Wind velocity measuring instruments, factor affecting the wind energy output, Principles and performance analysis of wind pumps. Design concept and testing. Principles of wind electric generators, basic characteristics of electric generators. variable and constant speed machines. Mechanical considerations and speed coupling, stand along, grid interconnected wind turbine. Grid interconnection and instrumentation, system stability. Aerodynamic design principles; Aerodynamic theories, axial momentum, blade element and combined theory. Rotor characteristics, wind turbine design considerations, methodology, and theoretical simulation of turbines loss, modeling of wind turbines and testing methods. Aerodynamic, mechanical breaking mechanisms, control, dynamics of large wind turbine systems, instrumentation, control and economics.
Importance and place of hydropower in the total power scenario in India, comparison with thermal and nuclear power; economic and environmental considerations. Hydrology: Descriptive hydrology; Hydrograph; Mass curve; Storage; Dams. Water ways: Pressure conduits; Penstocks; Water hammer; Surge tanks. Selection of hydro–turbines and their accessories; Hydro-turbine design, installation, operation and maintenance. Tidal power plant, pumped hydro storage plant and multipurpose hydroelectric projects.

Course-outcomes:

CO1: Students will be able analyze fluid power energy conversion systems through suitable methods of testing, modeling and theoritical simulation.
CO2: Students will be able to design renewable fluid power systems such as wind and hydro turbines, tidal power and pumped-hydro storage systems.
CO3: Students will be able to predict the cause of malfunctioning of different components associated with a renewable fluid power system.
CO4: Students will be able to select appropriate measures during operation, installation and maintenance of the renewable fluid power systems.

Text Books:

1. Johnson G. L. *Wind Energy Systems* (Electronic Edition), Prentice Hall, New Delhi, 2006.
2. Wagner H. and Mathur J. *Introduction to Hydro energy Systems: Basics, Technology and Operation*, Springer, 2011

References:

1. Hau E. *Wind Turbines: Fundamentals, Technologies, Application and Economics*, Springer, 2000.

2. Mathew S. *Wind Energy: Fundamentals, Resource Analysis and Economics*, Springer, 2006
3. Burton T. Sharpe D. Jenkins N. and Bossanyi E. *Wind Energy Handbook*, John Wiley, 2001
4. Nag P. K. *Power Plant Engineering*, Third Edition, Tata McGraw Hill, 2008.

ME552: Renewable Thermal Power Technology L-T-P-CH-CR:3-0-0-3-3

Introduction to solar science, environment and different angles, Methodologies for Solar thermal conversion system, Solar thermal conversion coating technology, General description of solar thermal collectors – Flat plate collectors, improved design of solar thermal collector for enhanced heat transfer, Concentrating collectors, evacuated collector, Design of various types of Solar collectors, Performance of solar collectors ; ASHRE codes, Solar active and passive heating ; Solar cooling ; Conversion to mechanical energy ; Solar desalination, Solar drying, Industrial application, Solar energy storage ; Solar thermal power plant, Economics of solar processes; Modeling of solar thermal systems, Components and simulation ; Design and sizing of solar heating systems.

Biomass resource assessment, properties of biomass and its analysis, different energy conversion methods – combustion, gasification, pyrolysis, liquification, biomass pre-treatment and processing, Biomethenation technology, bio-diesel, improved wood stove, bio-hydrogen generation, electricity generation from biomass gasifier, cooling and cleaning methods of gas produced from gasifier, engine systems, petrol, diesel and duel fuel engine and purely producer gas fired technology.

Course outcomes:

CO1: The students will understand solar science and utilization of solar thermal energy.
CO2: The students will be able to perform necessary analyse on concentrating collectors, evacuated collector, design of various types of solar collectors, performance of solar collectors; ASHRE standards.
CO3: The students will be able to perform mathematical analysis for solar desalination technology, solar drying, industrial applications, solar thermal power plant, and economics of solar thermal processes.
CO4: The students will be able to perform analysis on solar thermal energy storage; design of sensible and latent heat storage system for solar thermal power plants and economics.
CO5: The students will be able to perform mathematical and practical analysis on combustion, gasification, pyrolysis, liquification, biomass pre-treatment and processing, bio-methenation technology.
CO6: Students will be able to perform experiments on improved wood stove, bio-hydrogen biodiesel generation, purely producer gas fired technology, engine modifications for electrical power generation.

Text Books:

1. Nayak, J. K. and Sukhatme, S. P. *Solar Energy: Principles of Thermal Collection and Storage*, Tata McGraw Hill, New Delhi, 2006.
2. Mukunda, H. S. *Understanding Clean Energy and Fuels from Biomass*, Wiley India, 2011

References:

1. Duffie J. A. and Beckman W. A. *Solar Engineering of Thermal Processes*, John Wiley, 2006
2. Goswami D. Y. Kreith F. and Kreider J. F. *Principles of Solar Eng*ineering, Taylor and Francis, 1999.
3. Garg H. P. and Prakash S. (1997); *Solar Energy: Fundamental and Application*, Tata McGraw Hill, 1997
4. Kishore V. V. N. *Renewable Energy Engineering and Technology*, TERI, 2009
5. Tiwari G. N. *Solar Energy: Fundamentals, Design, Modelling and Applications*, Narosa, 2002
6. Basu P. *Biomass Gasification and Pyrolysis: Practical Design and Theory*, Academic Press, New York, 2010

7. Loo S. V. and Koppejan J. *The Handbook of Biomass Combustion and Co-firing*, Earthscan, London, 2008.

ME-553: Refrigeration System and Component Design **L-T-P-CH-CR: 3-0-0-3-3**

Review of Basic Refrigeration Systems: Overview of Vapour-compression cycles, Multi-pressure systems, Vapour absorption cycles and Aircraft refrigeration cycles, Effects of operating parameters on the performance of the refrigeration cycles

Refrigerant compressors: Thermodynamic processes during compression, effect of clearance on work, capacity control of refrigerant compressors, construction features of reciprocating compressors, rotary compressors, screw compressors, scroll compressors, centrifugal compressors, performance characteristics of centrifugal compressors, comparison of performance of reciprocating and centrifugal compressors, Lubrication oil and their compatibility issues.

Condensers and Evaporators: Heat rejection ratio, types of condensers, heat transfer analysis in condensers, Wilson's plot, Types of evaporators, heat transfer in evaporators, extended surface evaporators, augmentation of boiling hat transfer, pressure drop in evaporators. A simple comparison between water cooled and air-cooled based condenser Air-conditioning plants.

Expansion Devices: Types of expansion devices, automatic or constant pressure expansion valve, thermostatic-expansion valve, capillary tube and its sizing

Refrigerants: A survey of refrigerants, designation of refrigerants, selection of a refrigerant, thermodynamic, physical and chemical requirements, ozone depletion potential and global warming potential of CFC refrigerants, Substitutes for CFC refrigerants

Design of complete vapour compression system: The complete system, graphical method, analytical method, Newton-Raphson method, Optimal design of evaporator

Vapour absorption system: Common refrigerant-absorbent systems, modifications to simple vapour-absorption system, Thermodynamic analysis of LiBr – H_2O and H_2O-NH_3 systems.

Course outcomes:

The contents which are covered in "**Refrigeration and air conditioning**" are the concepts towards Mechanical Engineering in industrial and domestic applications. Towards the end of the course the student would be able to:

CO1: Familiarize with the terminology associated with refrigeration system

CO2: Understand the components, system integration, and system design

CO3: Evaluate the various types of refrigeration system components and analyze the heat transfer process in the vapour compression cycle

CO4: Apply the concept of numerical, graphical and analytical methods for optimized design of refrigeration system

CO5: Discuss the modifications to simple vapour absorption system and describe the thermodynamic analysis of common refrigerant- absorbent system

Text Books

1. C. P. Arora, "*Refrigeration and Air conditioning*", Third Edition, Tata McGraw Hill, 2009.
2. W. F. Stoecker, "*Refrigeration and Air conditioning*", McGraw-Hill, New York, 1958.

References:

1. K. E. Herold, R. Radermacher and S. A. Keli, *Absorption Chillers and Heat Pumps*, CRC Press,

1996.
2. T.H.Kuehn, J W Ramsey and J L Therelkeld, *Thermal Environmental Engineering*, 3rd Edition, Prentice Hall, 1998.

ME-603: Thermal power generation systems L-T-P-CH-CR: 3-0-0-3-3

Fundamentals of Thermodynamics: Introduction, Thermodynamic Properties and Basic Concepts, Laws of Thermodynamics, Exergy, Energy and Exergy balance, Efficiency Definitions.
Vapor power generation: The Rankine cycle, Carnotization of the Rankine cycle, Equivalent Carnot model and its analysis, parametric study of the Rankine cycle to investigate effect of turbine inlet temperature (TIT) boiler and condenser pressure on efficiency and power through thermodynamic modelling, optimization of the boiler pressure and selection of optimum boiler pressure**.**
Reheat cycle, effect of reheat pressure on power and efficiency, determination of optimal reheat pressure for maximum efficiency and power output, regenerative cycle with open and closed water heater, carnotization of the regenerative cycle, optimum degree of regeneration, analysis of cogeneration and tri-generation plants, working fluids for Rankine cycles and their selection, Organic Rankine cycle, Kalina cycle
Nuclear power generation: Nuclear fuels, Fission, Nuclear fission Reactions, Nuclear reactors: boiling water reactor, pressurized water reactor, High temperature gas cooled reactors, heat transfer and fluid flow analysis in nuclear reactor, Nuclear-Based Cogeneration Systems, Super critical vapor power cycle with single and double reheat.
Combined cycle power generation: Coupled cycles, Combined cycle (CC) plants, Gas turbine- steam turbine plant, supplementary firing, heat recovery steam generator, single pressure, dual pressure and triple pressure steam cycles
Advanced power generation systems: Supercritical Pulverized Coal Combustion, integrated gasification combined cycle (IGCC), steam injected gas turbine (STIG), Fluidized Bed Combustion (FBC) with sorbent injection, Pressurized Fluidized Bed Combustion (PFBC), Combined heat and power (CHP), Integrated Gasification Humid Air Turbine, Indirectly fired power systems (IFPS)

Course-outcomes:

On successful completion of this course, the graduates will be able to

CO1: Analyze and present the thermodynamic performances of reheat and regenerative vapor power cycles with the help of thermodynamic modeling.
CO2: Analyze and present the thermodynamic performances of cogeneration and tri generation plants.
CO3: Analyze and present the thermodynamic performance of the organic Rankine cycle with various organic fluids.
CO4: Carry out and present heat transfer and fluid flow analysis in nuclear reactor.
CO5: Present and analyze the nuclear-based cogeneration systems.
CO6: Present thermodynamic analysis of combined power cycles involving steam cycles, organic Rankine cycles and Kalina cycles etc.
CO7: Present the technical details of supercritical pulverized coal combustion and fluidized bed combustion.
CO8: Write all technical details about the advanced power generation systems such as
  (i) integrated gasification combined cycle,
  (ii) integrated gasification humid air turbine,
  (iii) steam injected gas turbine (STIG), and indirectly fired power systems etc.

Text Books:

1. P.K.Nag, *Power Plant Engineering*, 2nd edition, Tata McGraw-Hill Education, 2002
2. C. Zamfirescu, I. Dincer. *Advanced Power Generation Systems*, Elsevier Science 2014, Netherland

References:

1. R. Kehlhofer, B. Rukes, F. Hannemann, F. Stirnimann, *Combined-Cycle Gas &Steam Turbine Power Plants*, 3rd Edition, PennWell corporation 2009.