CURRICULUM

July 2019 admission onwards

APPROVED BY

BOARD OF STUDIES (BOS)
MEETING, February 20, 2019

MTech in Thermal Engineering

DEPARTMENT OF MECHANICAL ENGINEERING

Dr B R AMBEDKAR NATIONAL INSTITUTE OF TECHNOLOGY, JALANDHAR

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Annexure-F

DR B R AMBEDKAR NATIONAL INSTITUTE OF TECHNOLOGY

JALANDHAR
Teaching Scheme and Syllabus
of
Regular MTech in Thermal Engineering

DEPARTMENT OF MECHANICAL ENGINEERING

SCHEME OF INSTRUCTION AND DETAILED SYLLABI

MASTER OF TECHNOLOGY IN THERMAL ENGINEERING

EFFECTIVE FROM JULY, 2019 ONWARDS

Course Scheme for MTech in Thermal Engineering

FIRST SEMESTER				
S.No.	**Course No.**	**Subjects**	**L-T-P**	**Credit**
1.	MA-553	Computational Methods in Engineering	3-0-0	3
2.	ME-551	Advanced Thermodynamics	3-0-0	3
3.	ME-553	Advanced Heat Transfer	3-0-0	3
4.	ME-555	Computational Fluid Dynamics	3-0-0	3
5.	ME-XXX	Programme Elective-I	3-0-0	3
6.	ME-561	Advanced Heat Transfer Lab	0-0-3	2
7.	ME-563	Computation and Simulation Lab	0-0-3	2
		Total	**15-0-6**	**19**

SECOND SEMESTER				
S.No.	**Course No.**	**Subjects**	**L-T-P**	**Credit**
1.	ME-552	Advanced Fluid Mechanics	3-0-0	3
2.	ME-554	Combustion and Emissions in IC Engine	3-0-0	3
3.	ME-556	Design and Optimization of Thermal Systems	3-0-0	3
4.	ME-XXX	Programme Elective-II	3-0-0	3
5.	ME-XXX	Programme Elective-III	3-0-0	3
6.	ME-562	Thermal Comfort and Building Energy Simulation Lab	0-0-3	2
7.	ME-564	Engines and Unconventional Fuels Lab	0-0-3	2
		Total	**15-0-6**	**19**

THIRD SEMESTER				
S.No.	**Course No.**	**Subject**	**L-T-P**	**Credit**
1.	ME-600	Project Work for MTech Dissertation, Part-I	0-0-12	6
2.	ME-601	Independent Study	0-0-6	3
3.	ME-558	Heat Exchangers	3-0-0	3
4.	ME-XXX	Programme Elective-IV	3-0-0	3
		Total	**6-0-18**	**15**

FORTH SEMESTER				
S.No.	**Course No.**	**Subject**	**L-T-P**	**Credit**
1.	ME-600	Project Work for MTech Dissertation, Part-II	0-0-24	12
		Total	**0-0-24**	**12**

Summary				
Semester	**I**	**II**	**III**	**IV**
Semester-wise total credit	**19**	**19**	**15**	**12**
Total credits	**65**			

Credit Distribution for MTech in Design Mechanical Engineering					
Category	**Sem - I**	**Sem - II**	**Sem - III**	**Sem - IV**	**Total No. of Credits to be earned**
Core Courses	**9**	**9**	**-**	**-**	**18**
Electives	**6**	**6**	**6**	**-**	**18**
Lab Courses	**4**	**4**	**-**	**-**	**8**
Seminar	**-**	**-**	**3**	**-**	**3**
Dissertation	**-**	**-**	**6**	**12**	**18**
Total	**19**	**19**	**15**	**12**	**65**

Programme Electives				
S.No.	**Course Code.**	**Subjects**	**L-T-P**	**Credit**
1	ME-565	Advanced IC Engines	3-0-0	3
2	ME-566	Advanced Power Plant Cycles	3-0-0	3
3	ME-567	Advanced Steam Power Plants	3-0-0	3
4	ME-568	Aerodynamics	3-0-0	3
5	ME-569	Alternative Fuels for IC Engines	3-0-0	3
6	ME-570	Applied Combustion	3-0-0	3
7	ME-571	Combustion Generated Pollution and Control	3-0-0	3
8	ME-572	Cryogenic Engineering	3-0-0	3
9	ME-573	Exergy Analysis of Thermal and Energy System	3-0-0	3
10	ME-574	Experimental Methods and Analysis	3-0-0	3
11	ME-575	Gas Dynamics	3-0-0	3
12	ME-576	Gas Turbines and Jet Propulsion	3-0-0	3
13	ME-577	Measurements in Thermal Engineering	3-0-0	3
14	ME-578	Microscale Transport Phenomena	3-0-0	3
16	ME-579	Multi-Phase Flow and Heat Transfer	3-0-0	3
17	ME-580	Optimization Theory	3-0-0	3
18	ME-581	Photovoltaic Cell and its Applications	3-0-0	3
19	ME-582	Refrigeration Systems and Components Design	3-0-0	3
20	ME-583	Renewable Energy	3-0-0	3
21	ME-584	Solar Passive Design and Sustainable Buildings	3-0-0	3
22	ME-585	Thermal Behaviour of Advanced Materials	3-0-0	3
23	ME-586	Turbomachinery	3-0-0	3
24	ME-587	Waste Heat Utilization and Polygeneration	3-0-0	3

First Semester

MA-553	Computational Methods in Engineering	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand the stepwise procedure to completely solve a fluid dynamics problem using computational methods
CO2	Ability to solve ODE problems using power series solutions
CO3	Ability to solve PDE using various analytical methods
CO4	Development of a clear understanding on Tensors, their operation and applications.

In relation to mechanical engineering applications, such as, heat transfer, fluid mechanics, vibrations, dynamics and others, the following topics will be covered:

Partial differential equations: Characteristics and classification of 2^{nd} order PDEs. separation of variables special functions, Eigen function expansions, Fourier integrals and transforms, Laplace transforms, methods of characteristics, self-similarity.

Linear algebra: Matrix theory, solution of linear system of algebraic and differential equations; round-off errors, pivoting and ill-conditioned matrices. Eigenvalues and eigenvectors.Unitary, Hermitian and normal matrices.

Numerical Methods: Lagrange interpolation, splines, integration – trapezoid, Romberg, Gauss, adaptive quadrature. Explicity and implicity methods, multi-step methods, Runge-Kutta and predictor-corrector methods, boundary value problems, eigenvalue problems, systems of differential equations, stiffness.Accuracy, stability and convergence.Alternating direction implicity methods.Non-linear equations.

Books Recommended

1. Ames W F, "NumericalMethods for Partial Differential Equations", 3rd Edition, Academic Press, New York (1992).
2. Dahlquist G and Björck A, "Numerical Methods", Prentice-Hall, NJ (1974).
3. Jain M K, Iyengar S R K. and Jain R K, "Numerical Methods for Scientific and Engineering Computations", 4th Edition New Age International (P) Limited, Publishers, New Delhi (2003).
4. Shampine L F, "Numerical Solution of Ordinary Differential Equations", Chapman and Hall, New York (1994).
5. Kreyszig, E., "Advanced Engineering Mathematics", 8th Ed, John Wiley, Singapore, 2002.

ME-551	**Advanced Thermodynamics**	**(3 0 0 3)**

Course Outcomes: At the end of the course the student will be able to:

CO1	Ability to solve thermodynamics relations and obtain thermodynamic efficiency
CO2	Ability to analyze problems persisting with real and ideal gas
CO3	Ability to solve stability and phase relations
CO4	Understanding of the concept of reactive mixtures.

Recapitulation of fundamentals.The two laws of thermodynamics–Caratheodory's formulation, analysis of typical simple closed systems, analysis of open systems–exergy analysis.Multicomponent systems–concepts of fugacity, chemical potential.General conditions for thermodynamic equilibrium–instability of thermodynamic equilibrium and phase transition.Thermodynamics of reactive mixtures.Elements of irreversible thermodynamics.

Books Recommended

1. Cengel& Boles, " Thermodynamics-An Engineering approach".5th Ed, Tata McGraw Hill
2. Winterbone, Desmond E, " Advanced Thermodynamics for engineers",1997,Elsevier
3. Annamalai, Puri, Ishwar.K. "Advanced Thermodynamics Engineering"2002,CRC Press.
4. Nag,P.K., " Engineering Thermodynamics",4th ed., Tata Mcgraw Hill.

ME-553	Advanced Heat Transfer	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand both the physics and the mathematical treatment of the advanced topics pertaining to the modes of heat transfer
CO2	Ability to formulate heat transfer conduction and radiation problems using ODE's and PDE's and obtain analytical solution
CO3	Apply principles of heat transfer to develop mathematical models for uniform and non-uniform fins
CO4	Analyze free and forced convection problems involving complex geometries with proper boundary conditions
CO5	Apply the concepts of radiation heat transfer for enclosure analysis.

Review of basic heat transfer, Introduction to Conduction, convection and radiation heat transfer, 1-D Steady State Heat Conduction, Fins with variable cross-section, generalized equation for fins, Fins of parabolic and triangular profiles, Transient in lumped systems, Multi-Dimensional Conduction, Analytical and numerical methods for solving multi-dimensional problems, Graphical method, Conduction shape factor, Analogical method, Relaxation Technique, Finite Difference method, Convective Heat Transfer, Momentum and Energy Integral Equation, Thermal and hydrodynamic boundary layer thickness, Heat transfer in a circular pipe in laminar flow when constant heat flux and constant wall temperature to the wall of the pipe, convection correlations for turbulent flow in tubes, Flow over cylinders and spheres, Flow across tube bundles/banks, Natural convection, Heat transfer from a vertical plate using the Integral method, Free convection in enclosed spaces, Mixed convection, Introduction to Boiling and Condensation Heat Transfer,Thermal radiation, Review of basics of surface radiation, non gray body, radiation shape factor, Hottel's Crossed String Method for finding shape factor, Radiosity and irradiation formulation, radiation shield and Gas radiation, Heat Exchangers, Review of basic concepts, Tubular and plate type heat exchanger, Overall heat transfer coefficient, LMTD, correction factor, Effectiveness, Introduction to design of heat exchangers.

Books Recommended

1. M.N. Ozisik, *Basic Heat Transfer*, Mc-Graw Hill, Inernational edition, 1988
2. J.P. Holman, *Heat Transfer*, McGraw Hill, 10th edition, 2010
3. F. Incropera, and D. J. Dewitt, *Introduction to Heat Transfer* –Wiley & Sons Inc., 6th edition,2010.
4. F. Kreith, *Principles of Heat Transfer*, Harper & Row, New York, 4th edition, 1986.
5. Gupta and Prakash, *Engineering Heat Transfer*, New chand& Bros, 4th edition
6. Bejan, *Convective Heat Transfer*, J. Wiley & Sons, 2nd edition, 1995.
7. S.P. Venkateshan, *Heat Transfer*, Ane Publication, 2009.
8. P.S.Ghoshdastidar, *Heat Transfer*, Oxford, Univ press, 2nd edition, 2012.
9. Domkundwar and Arora, *A Course in Heat and Mass Transfer*, DhanpatRai& Sons, 7th edition 2008.

ME-555	Computational Fluid Dynamics	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand CFD as a tool, need for development and analysis in fluid dynamics and heat transfer problems
CO2	Handle ordinary and partial differential equations, and their linearization using CFDtechniques
CO3	Understand basic concept of FVM and its implementation on heat transfer and fluid dynamics problems
CO4	Develop codes for various fluid dynamics and heat transfer problems based on CFD.

Review of basic fluid mechanics and the governing Navier-Stokes equations, Techniques for solution of PDEs – finite difference method, finite element method and finite volume method, Finite volume (FV) method in one dimension, Differencing schemes, Steady and unsteady calculations, Boundary conditions, FV discretization in two and three dimensions, Simple algorithm and flow field calculations, variants of SIMPLE, Turbulence and turbulence modeling, illustrative flow computations, Commercial softwares FLUENT and CFX – grid generation, flow prediction and post-processing.

Books Recommended

1. S V Patankar, *Numerical Heat Transfer and Fluid Flow*, McGraw Hill, NY, 2005.
2. John Anderson, "*Computational Fluid Dynamics*", McGraw-Hill Publication, First edition,1995
3. W M Kays and M E Crawford, *Convective Heat and Mass Transfer*, Mc-Graw Hill, New York 1993.
4. F M White, *Viscous Fluid Flow* by, Mc-Graw Hill, New York, 2nd Ed. 1991.
5. Robert Siegel and John Howell, *Thermal radiation Heat Transfer*, 4th Edition, Taylor and Francis NY, 2002.

ME-561	Advanced Heat Transfer Lab	(0 0 32)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand in utilizing the lab equipments for research purpose. Ability to conduct experiments and validate with the theoretical/analytical results
CO2	Understand heat transfer during charging and discharging of PCM in thermal energy storage system
CO3	Understand the flow patterns across different types of bodies using CCD camera. Understanding of thermal and hydrodynamic boundary layer for flow over surfaces
CO4	Understand the performance of different type of heat exchanger, spray cooling on a flat surface. Understanding of statistical analysis of the results.

List of Experiments

1. Evaluation of effect of surface roughness on heat transfer characteristics for absorber plate of solar flat plate collector. Perform statistical analysis of the results.
2. Evaluate the heat transfer characteristics for swirling flames impinging on the flat surface. Perform statistical analysis of the results.
3. Evaluate heat transfer during charging and discharging of PCM in thermal energy storage system.
4. Evaluate the thermal efficiency during charging, storing and discharging the PCM in thermal energy storage system and further evaluate the overall system thermal efficiency.
5. Evaluate the flow patterns across different types of streamline bodies and bluff bodies at different temperatures using CCD camera.
6. Evaluate the thermal and hydrodynamic boundary layer for flow over surfaces.
7. Evaluate the performance of shell and tube conventional and compact type heat exchanger.
8. Evaluate the performance of the spray cooling on a flat surface.

ME-563	Computation and Simulation Lab	(0 0 32)

Course Outcomes: At the end of the course the student will be able to:

CO1	Formulation and solution of problems in fluid flow and heat transfer
CO2	Understand the discretization of differential equations, provide boundary conditions and obtain numerical solution for fluid and heat transfer problems
CO3	Develop codes for numerical methods to solve 1D and 2D heat conduction and convection problems

CO4	Use commercial software like ANSYS, open foam etc. for solving real life engineering problems.

<u>List of Experiments</u>

1. To study 2D Laminar and turbulent flow problems using CFD codes/tools and validation with Blasius equation.
2. To study formation of flat plate boundary layer (2D) using CFD codes/tools and validation the results with analytical correlations.
3. To study the turbulent forced convection problem in a pipe using CFD codes/tools considering top and bottom walls as a constant wall temperature boundary condition and validation the results with Dittus-Boelter equation.
4. To study flow past a cylinder in steady state using CFD Code/tools.
5. To study flow past a cylinder in unsteady state using CFD Code/tools.
6. To study compressible Flow in a Nozzle using CFD Code/tools.
7. To study the free fall of droplet using CFD Code/tools and validate results with High speed camera images.
8. To study the rise of the bubble using CFD Code/tools and validate results with High speed camera images.
9. To study two phase flow in a microchannel with micro cavity using CFD Code/tools and validate results with High speed camera images.

Second Semester

ME-552	Advanced Fluid Mechanics	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Ability to apply knowledge of fluid mechanics in research and technology
CO2	To enable the students to learn about the mathematical modeling techniques for fluid mechanics problems
CO3	To enable the students to understand the importance of analytical approximate solutions
CO4	Ability to understand and solve complex turbulent flow problems.

Review of basic laws of fluid flow in integral and differential form, kinematics, Ideal fluid flow. Newtonian fluid flow and applications, Creeping flow, Boundary layer theory, Transition and turbulence turbulent boundary layer Fundamentals of compressible flows Modelling and dimensional analysis.

Books Recommended

1. Douglas J F. Gasionckw, and Swaffield JP “Fluid Mechanics” 3rd edition AddisionWesley Longman, IncPitman, 1999.
2. Pao H F Richard “Fluid Mechanics” John Wiley and Sons. 1995
3. Kumar DS “Fluid Mechanics and Fluid Power Engineering” 6th edition SK KatariaandSons, Delhi. 1998.
4. Streeter V L and Wylie E B “Fluid Mechanics” McGraw Hill International.
5. Bansal R K “ A text book of Fluid mechanics and Hydraulic Machines” 8th edition, LaxmiPublications Ltd. New Delhi, 2002.
6. Mohanty A K, “Fluid Mechanics”, 2nd Edition Prentice Hall of India Private Limited, NewDelhi, 2002.

ME-554	Combustion and Emissions in IC Engine	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To study the various properties of IC engine fuels and determination of air required for combustion
CO2	To study the various stages of combustion in SI and CI engines and understand the normal and abnormal combustion phenomena
CO3	To study the kinetics of CO, HC, NOx, their measurement and emission control strategies to conform to legislation standards
CO4	To study various alternative fuels for IC engines and their effect on performance and emission characteristics.

Fuels: Important qualities of SI and CI engine fuels and their ratings. Combustion of Fuels: Heating values of Fuels – SI engine fuels – CI engine fuels – Determination of minimum air required for combustion, conversion of volumetric analysis to mass analysis, Determination of air supplied from volumetric analysis of Dry flue gases,

Combustion in SI Engines: Stages of combustion, Flame front propagation– Factors influencing flame speed, Thermodynamic analysis:Burned and unburned mixture states. Analysis of cylinder pressure data, Combustion process characterization, Flame structure and speed; flame structure, laminar burning speeds, flame propagation relations, Cyclic variations in combustion, partial burning and misfire: definitions, causes of cycle – by – cycle and cylinder to cylinder variations, partial burning, misfire and engine stability. Spark Ignition: Ignition fundamentals, conventional ignition systems, alternative ignition systems, alternative ignition approaches, Abnormal Combustion: knock and surface ignition, knock fundamentals, fuel factors.

Combustion in CI Engines: Stages of combustion in CI Engine – Ignition delay – Factors effecting ignition delay, physical properties affecting delay, Types of diesel combustion systems: Direct injection systems, indirect injection systems, Analysis of cylinder pressure data; combustion efficiency, DI engines, IDI engines, Fuel spray behavior: Fuel injection, overall spray structure, atomization, spray penetration, droplet size distribution and spray evaporation, Ignition delay: definitions and discussion, fuel ignition quality, auto ignition fundamentals, effect of fuel properties.

Emission and Control: Emission of various pollutants from the engine, Kinetics of NOx, HC and CO formation in SI and CI Engines, Measurement of Emissions, Exhaust gas treatment. Emission Standards

Alternative Fuels – Alcohols **-** CNG – LPG – Hydrogen **-** Biodiesels – Biogas **-** Dual fuel operation. Performance and Emission Characteristics of SI and CI Engines using these alternatefuels.

Books Recommended

1. John. B.Heywood, *Internal Combustion Engine Fundamentals*, McGraw Hill, 1988.
2. E.F. Obert, *Internal Combustion Engine and Air Pollution*, Harper and Row Publishers, 1973.
3. V.L. Maleeve, *Internal Combustion Engines*, McGraw Hill Book Company, 1945.
4. Colin R.Ferguson and Allan T.Kirkpatrick, *Internal Combustion Engines*, Wiley publishers, 2000.
5. Mathur& Sharma, *Internal Combustion Engines*, Dhanpatrai Publishers. 2006.
6. V.Ganesan, *Internal Combustion Engines*, Tata McGraw Hill, 2003.
7. H.N.Gupta, *Fundamentals of Internal Combustion Engines*, PHI, New Delhi, 2006.
8. PulkRabek W W, *“Engineering Fundamentals of Internal Combustion Engine”,* Pearson EducationNew Delhi (2003).

ME-556	Design and Optimization of Thermal Systems	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To understand the various Thermal systems encountered in Engineering along with the importance of their associated parameters
CO2	To apply the various concepts learnt in the subjects of Thermodynamics, Fluid Mechanics, Heat Transfer and Applied Mathematics to predict and simulate the performance of Thermal systems
CO3	To understand the different Optimization techniques and develop the skills to Model and analyze the various Thermal systems
CO4	To develop skills to solve single as well as Multivariable optimization problems.

Introduction to Design and Analysis, and Project Initiation, Review of Fluid Mechanics, Thermodynamics & Heat transfer, System identification and description & component design: Heat exchangers, Prime movers, System Design and Optimization Techniques and Economic Evaluation, Engineering economics.

Books Recommended

1. Stoecker, W., Design of Thermal Systems, McGraw-Hill
2. Burmeister, L.C., Elements of Thermal-Fluid System Design, 1998,Prentice Hall
3. Jaluria, Y., Design and Optimisation of Thermal Systems, 2007,McGraw-Hill,
4. Janna, W.S., Design of Fluid Thermal Systems, 1993,PWS-Kent Publishing, 1993.

ME-562	Thermal Comfort and Building Energy Simulation Lab	(0 0 3 2)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understanding the basic principles and fundamentals of mechanical engineering systems in the building engineering science
CO2	To understand basic principle of engineering to design and analyze various types of mechanical systems in built environment
CO3	To provide a bird eye view and holistic approach of modeling and simulation of mechanical systems for energy efficiency and sustainable development.

<u>List of Experiments</u>

1. PV Solar systems modeling and analysis
2. Introduction to building energy simulation tools i.e. e-Quest, Energy plus, TRNSYS
3. Modeling techniques, validation of simulation model
4. Simulation for energy efficiency of buildings
5. Simulation for ECBC code compliance by whole simulation method

ME-564	Engines and Unconventional Fuels Lab	0 0 3 2)

Course Outcomes: At the end of the course the student will be able to:

CO1	To make the students understand the functioning of various sensors and actuators in an Engine
CO2	To make students understand the effect of EGR on NOx emissions
CO3	To make the students understand the effect of various engine parameters on performance and combustion characteristics
CO4	To enable the students understand the determination of Uncertainty in measurements.

List of Experiments

1. To measure the properties of the fuel
   a. Acid Number
   b. Viscosity of oils/ liquid fuels
   c. Density and specific gravity of oils/ liquid fuels
2. Study of Performance characteristics of a Single Cylinder DI engine and its comparison with similar CRDI engine
3. Study of Various sensors and actuators required for an open ECU based CRDI engine.
4. Study of Performance and combustion characteristics of multicylinder CRDI engine.
5. Utilization of Exhaust Gas Recirculation (EGR) for reduction of NOx emissions in compression ignition engine.
6. To perform an Uncertainty analysis on engine performance and combustion parameters.

Third Semester

ME-558	Heat Exchangers	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To introduce basic heat transfer mechanisms in heat exchangers; Classification of Heat Exchangers
CO2	To understand and apply the different heat transfer and pressure drop correlations for single and two phase flows
CO3	To understand the concepts related to Thermal and Hydraulic designs of heat exchangers and perform calculations for the design of Double pipe, Shell and Tube and compact Heat Exchangers
CO4	To understand the concepts of Fouling and its impact on thermal design of heat Exchangers
CO5	To introduce the various commercial soft wares available to design the various types of Heat Exchangers.

Applications.Basic design methodologies – LMTD and effectiveness-NTU methods. Overall heat transfer coefficient, fouling. Correlations for heat transfer coefficient and friction factor. Classification and types of heat exchangers and construction details. Design and rating of double pipe heat exchangers, compact heat exchangers, plate and heat pipe type, condensers, cooling towers. Heat exchanger standards and testing, Heat transfer enhancement and efficient surfaces.Use of commercial software packages for design and analysis, optimization.

Books Recommended

1. Kays and London, "Compact Heat Exchangers", McGraw Hill.
2. Hesselgreaves, "Compact Heat Exchangers Selection, Design & Operation", Pergamon.
3. Shah, R.K. &Sekulic D.P, "Fundamentals of Heat Exchanger Design", John Wiley & Sons.
4. Kakac& Liu, " Heat Exchangers-Selection, Rating and Thermal Design", 2nd ed.,CRC Press

Programme Electives

ME-565	Advanced IC Engines	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To expose the students to various air standard and fuel air cycles and the reasons for the deviation of real cycles from ideal cycles
CO2	To enable the students to do the performance analysis of IC Engine and justify the suitability of IC Engine for different applications
CO3	To study the new trends in engines with an aim to improve the performance and emission characteristics
CO4	To study the recent trends in Engine Management System

Cycle Analysis: Otto, diesel, dual, Sterling and Brayton cycles, comparison of air standard, fuel air and actual cycles, simple problems on the above topics.

Measurement and Testing: Measurement of IP. FP, BP, friction fuel consumption, air consumption, speed, emission.Performance Characteristics of SI and CI Engines, Engine performance maps, Heat Balance sheet.

Special Types of Engines: Introduction to working of stratified charged engines, Wankel engine, variable compression engine, Surface ignition engines, free piston engines, Current engines and future trends (e.g. Convergence of SI and CI engine technology, Control developments, fuel quality), Effect of air cleaners and silencers on engine performance.

Recent Trends: Homogeneous Charge Compression Ignition Engine, Lean Burn Engine, Stratified Charge Engine, Surface Ignition Engine, Four Valve and Overhead cam Engines, Electronic Engine Management, Common Rail Direct Injection Diesel Engine, Gasoline Direct Injection Engine, Data Acquisition System –pressure pick up, charge amplifier PC for Combustion and Heat release analysis in Engines.

Electronic Engine Management: Computer control of SI & CI engines for better performance and low emissions, closed loop control of engine parameters of fuel injection and ignition

Books Recommended

1. Heinz Heisler, ‘Advanced Engine Technology,” SAE International Publications,USA,1998 Ganesan V. “Internal Combustion Engines” , Third Edition, Tata Mcgraw-Hill ,2007
2. Tom Denton. “Automobile Electrical and Electronic Systems”, Elsevier, 2004
3. John B Heywood,” Internal Combustion Engine Fundamentals”, Tata McGraw-Hill, 1988
4. Richard Stone. “Introduction to Internal Combustion Engine”, Society of Automotive Engineers Inc 1999
5. Hua Zhao, NicosLadommatos. “Engine combustion instrumentation and diagnostics”, Society of Automotive Engineers, 2001
6. Robert Bosch GmbH.“Bosch Automotive Electrics and Automotive Electronics: Systems and Components, Networking and Hybrid Drive”, Springer View.

ME-566	Advanced Power Plant Cycles	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To acquire the knowledge on advanced power plant cycles such as combined cycle, Kalina cycle, zero emission cycle (hydrogen-oxygen cycle), nuclear cycle etc
CO2	To estimate irreversibilities of the power plant components for exergy analysis

CO3	To simulate and optimize the real cycles
CO4	To analyse the power plant at off-design conditions
CO5	To distinguish between various power generation units and choose one that meets desired economic, environmental and social requirements.

Review of various ideal cycles–Rankine and Brayton–and fuel-air cycles.Thermodynamics optimization of design parameters. Real cycle effects–internal and external irreversibilitites, pressure drops, heat loss, condenser air leakage, fouling of heat transfer surfaces, combustion losses–and their impact on the thermodynamic cycle. Optimization of real and double reheat cycles. Analysis of off-design performance.Combined cycles–ideal and real cycles–thermodynamic analysis.Design of alternate schemes for combined cycles– single, dual and triple pressure cycles, and their optimization. Retrofit of ageing power plants. Parametric analysis–effects of gas and steam cycle variables. Binary vapour and Kalinacycles.Thermochemical and H2-O2 cycles.Cycles for nuclear power plants (PWR, BWR, PHWR, FBR). All simulations will involve extensive use of numerical techniques as part of laboratory work.

Books Recommended

1. Wiesman J and Eckart R, “Modern Power Plant Engineering”, Prentice Hall,New Delhi ,1985.
2. Nag P K, “Power Plant Engineering”, Tata McGraw Hill,New Delhi ,1998.
3. Kostyuk.A and Frolov V, “Steam and Gas Turbines”, Mir Publishers, Moscow ,1988.
4. Aschner F S, “Planning Fundamentals of Thermal Power Plants”, John Wiley ,1978.
5. Eastop T D and McConkey, “Applied Thermodynamics”, Longman Scientific and Technical, 1986.

ME-567	Advanced Steam Power Plants	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To apply the knowledge of advanced thermal power plants from simple cycle to supercritical cycle
CO2	To design the components in thermal power plants and cogeneration plants such as boiler, condenser and other heat exchangers
CO3	To conduct the energy auditing and exergy evaluation
CO4	To analyse latest power augmentation techniques in thermal power plants
CO5	To know about the kind of boilers being used in various industries and their applicability.

Thermal Power Plant Engineering, Energy sources and scenario – Power Plant Cycles – Reheat – Regenerative, Supercritical -Coupled and combined – Cogeneration Plants, Exergy analysis of power plant cycles, Coal, its properties, combustion, Analysis and sizing of Power Plant Components: Steam generator, Condenser, Cooling tower and other heat exchangers, Power plant economics, energy audit. Recent trends in power production.

Books Recommended

1. R.W. Haywood, *Analysis of Engineering Cycles*, Pergamon Press, 1975.
2. A.W. Culp, *Principles of Energy Conversion*, McGraw Hill, 1979.
3. M.M. Elwakil, *Power Plant Technology*, McGraw Hill, 1984.
4. T.D. Eastop and A.McConkey, *Applied Thermodynamics*, ELBS, 1986.
5. P.K.Nag, *Power Plant Engineering*, Tata McGraw Hill, 2000.
6. J.Weisman, and R.Eckart, *Modern Power Plant Engineering*, Prentice Hall, 1985.

ME-568	Aerodynamics	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To develop knowledge in the field of potential flow theory and their applications in aerodynamics problems
CO2	To develop ability to model lift for flow over arbitrary cylinders
CO3	Understanding to model lift over airfoil using thin airfoil theory and Kutta-Jowkowski law
CO4	Understanding of laminar and turbulent boundary layer theory.

Aerodynamic forces and moments; continuity, momentum and energy equations; Inviscid incompressible flow – incompressible flow in a low speed wind tunnel, source and doublet flows, nonlifting flow over a circular cylinder, Kutta-Joukowski theorem; Incompressible flow over airfoils and finite wings – Kutta condition, Kelvin's circulation theorem, Biot-Savart law, Helmholtz vortex theorem, Prandtl's classical lifting line theory; Thin aerofoil theory; Three dimensional source and doublet; Inviscid compressible flow – normal and oblique shocks, expansion waves, supersonic wind tunnels; Elements of hypersonic flow, Newtonian theory; Equations of viscous flow; Laminar and turbulent boundary layers; Panel methods in aerodynamics.

Books Recommended

1. J.D. Jr.Anderson, *Fundamentals of Aerodynamics*, McGraw Hill
2. J.J. Bertin, *Aerodynamics for Engineers*, Pearson Education, 2002.
3. E.L. Houghton and N.B. Carruthers, *Aerodynamics for Engg. Students*, Arnold Pub., 1988.
4. A.M. Kuethe, and C.Y. Chow, *Foundations of Aerodynamics*, Wiley, 1998.
5. L.J. Clancy, *Aerodynamics*, Himalayan Books, 1996.

ME-569	Alternative Fuels for IC Engines	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Interpret and distinguish between the different types of conventional and non-conventional fuels
CO2	Demonstrate the utilization of synthetic and substitute fuels for practical applications
CO3	Describe various parameters that are utilized to characterize alternative fuels and its combustion process
CO4	Solve renewable energy related problems with knowledge in fossil fuels and alternative fuels
CO5	Demonstrate knowledge in production methods of different alternative fuels
CO6	Select from different alternative fuels available for specific potential applications
CO7	Understand the socio-economic, environmental impacts, limitations and applications of alternative fuels.

Hydrocarbon fuels: Crude petroleum oil and its refining, products of refining, availability of hydrocarbon fuels and their impact on environment.

Gasoline: Chemical composition, combustion characteristics of gasoline, Effect of various engine parameters on the combustion of gasoline; Knocking, Octane number, Effect of sulphur, ash forming additives, oxygenates, olefins, aromatics, benzene content.

Diesel: Chemical composition, combustion characteristics of diesel, Engine parameters affecting the combustion of diesel ; Cetane number, sulphur content, density, volatility, distillation characteristics.
Ethanol and Methanol: Benefits of using ethanol, methanol as fuel, their method of production, properties of ethanol, methanol, methods of using ethanol, methanol in diesel engines: Fumigation, solutions, Spark injection, dual injection, ignition improvers, surface ignition, low heat rejection.

Biodiesel: Definition, advantages of biodiesels, methods of producing biodiesels; blending, cracking, Transesterification, super critical methanol Transesterification, properties of biodiesels, emission characteristics of biodiesels.

Gaseous Fuels: LPG, LNG and CNG Composition, combustion characteristics, dispensing methods, emission studies. Hydrogen, its combustion characteristics, flashback control technique, safety aspects and system development.Biogas, producer gas, their method of preparation, their use as an engine fuel.

Books Recommended

1. Biodiesel, Basics And Beyond New Society Pub 2006
2. McGowan, Thomas Biomass and Alternate Fuel Systems: An Engineering and Economic Guide Wiley-AIChE 2009
3. Processing and Testing of Biodiesel Fuels Serials Publications 2009.

ME-570	Applied Combustion	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To enable the students to understand the fundamentals of combustion and different modes of burning
CO2	To understand the working of various combustion devices and their complicacies involved
CO3	To understand the key features required for developing technologies based on combustion process
CO4	To make students understand the future avenues in combustion technology.

Review of combustion fundamentals. Gas-fired furnace combustion.Oil-fired furnace combustion. Gas turbine spray combustion. Combustion of solids.Industrial applications involving combustion.Burner design, testing and control.Emissions.Combustion safety.

Books Recommended

1. Kenneth Kuan-yunKuo, Principals of Combustion, John Wiley and Sons, NY (2005).
2. Stephen R. Turns, An Introduction to Combustion: Concepts and Applications, 2nd Edition, Mc-Graw Hill, (2005).
3. Norbert Peters, Turbulent Combustion, Cambridge University Press, First Ed. (2000).

ME-571	Combustion Generated Pollution and Control	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand the fundamental knowledge of thermodynamics and chemical kinetics of combustion
CO2	Apply the general principles of combustion of fuels
CO3	Explain the formation mechanisms of combustion-generated air pollutants
CO4	Understand and select appropriate methods for air pollution measurement and control
CO5	Determine the air pollutant concentration and dispersion from sources.

Generation and nature of pollutants from various combustion sources, their effects on health and the environment.Emissionindices.Thermo-chemistry of pollutant formation, stoichiometry, chemical thermodynamics, kinetics.Pollutants from I.C. engines, power plants, domestic and other sources.Meteorology and dispersion of pollutants, instruments for pollutant measurement and monitoring.Legislation and emission standards.

Books Recommended

1. Edward f. Obert, Internal Combustion Engine and air pollution, Intent Education publishers.
2. John B.Heywood, Internal Combuston Engine Fundamentals, McGraw Hill Book, 1988.
3. Crouse William, Automotive Emission Control, Gragg Division/McGraw Hill, 1980.
4. Ernst S.Starkman, Combustion Generated air pollution, Plenum Press.
5. George Springer and Donald J.Patterson, Engine Emissions, Pollutant formation and measurement, Plenum press.
6. Obert.E F, IC Engines and air pollution, Intent Education publishers.

ME-572	Cryogenic Engineering	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To understand the various thermodynamics cycles used for cryogenics
CO2	To understand the practical applications of cryogenics in space, rocket, biotechnical applications
CO3	To develop understanding in the storage of working fluid used for cryogenics
CO4	To develop skill for the understanding of the type and phase of working fluid used for cryogenics.

Cryogenic Systems, Introduction, Insight on Cryogenics, Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures, Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction Cycles. Inversion Curve - Joule Thomson Effect, Liquefaction Cycles, LindeHampson Cycle, Precooled LindeHampson Cycle, Claudes Cycle, Dual Cycle, Helium Refrigerated Hydrogen Liquefaction Systems. Crtical components in Liquefaction Systems, Cryogenic Refrigerators: J.T.Cryocoolers, Stirling Cycle Refrigerators, G.M.Cryocoolers, Pulse Tube Refrigerators, Regenerators used in Cryogenic Refrigerators, Magnetic Refrigerators, Applications: Applications of Cryogenics in Space Programmes, Superconductivity, Cryo Metallurgy, Medical applications, Cryogenic heat transfer: applications, Material Properties at cryogenic temperatures, specific heats and thermal conductivity of solid, liquid and gases, Cryogenic insulations, gas-filled and evacuated powders and fibrous materials, microsphere and multi-layer insulations.

Books Recommended

1. R.B. Scott, *Cryogenic Engineering*, Van Nostrand and Co., 1962
2. Herald Weinstock, *Cryogenic Technology*, 1969
3. Robert W.Vance, *Cryogenic Technology*, Johnwiley& Sons, Inc., New York, London,
4. Klaus D.Timmerhaus and Thomas M.Flynn, *Cryogenic Process Engineering, Plenum Press*, 1989
5. Randall F.Barron, *Cryogenic Systems*, McGraw Hill, 1985.

ME-573	Exergy Analysis of Thermal and Energy System	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To enable the students to understand the exergy method of energy systems
CO2	To develop the knowledge of students in applying the exergy approach to solve the problems of thermal power plants
CO3	Design the thermal and energy systems with exergy approach
CO4	Do the exergetic analysis to find the bottlenecks in the process/component. Identify the drawbacks and recommend the modifications.

Concept of exergy – Available work – Exergy loss, Reversibility and irreversibility – exergy for control region – physical exergy and chemical exergy – closed system analysis – Exergy evaluation of solid, liquid and gaseous fuels – tables and charts.

Thermodynamic Properties: Combined first and second law equation-Maxwell relations - Clapeyron equation – internal energy, enthalpy, entropy, exergy – specific heats as a function of temperature and pressure.

Thermodynamic Equilibrium: Combustion – Combustion reactions - Enthalpy of formation - Entropy of formation - Reference levels for tables - Heat of reaction - Adiabatic flame temperature – General product – Enthalpies – Equilibrium – Chemical equilibrium of ideal gases – Effects of Non-reacting gases– Equilibrium in multiple reactions – The vont Hoff Equation – The chemical potential and phase equilibrium – The Gibbs Phase Rule.

Numerical methods: Use of numerical methods to solve the exergy problems with iterations.

Exergy Applied to Processes: Expansion process - compression process – heat transfer processes – mixing and separation processes – chemical process and combustion – Linde air liquefaction plant – CHP plant – GT-ST combined cycle plant – refrigeration plant – heat pump systems – fuel cell systems.

Thermoeconomic Applications of Exergy: Structural coefficients exergy losses – optimization of component geometry – thermoeconomic optimization of thermal systems – thermoeconomic optimization of heat exchanger in a CHP plant – exergy costing in multi product plant.

Books Recommended

1. Dinçer, Marc A. Rosen, 2007, Exergy: Energy, Environment, and Sustainable Development, Elsevier.
2. Lucien Borel, Daniel Favrat, Thermodynamics and Energy Systems Analysis: From Energy to Exergy (Engineering Sciences-Mechanical Engineering), 2010 EPFL Press.
3. Valero A., C. C., 2009, “Thermoeconomic Analysis,” Encyclopedia of Life Support Systems,Vol. Exergy, Energy System Analysis, and Optimization, Oxford, United Kingdom: EOLSS Publishers.
4. KalyanAnnamalai, Ishwar K. Puri, Milind A. Jog, 2011, Advanced Thermodynamics Engineering, Second Edition (Computational Mechanics and Applied Analysis), CRC Press.
5. Aloui, Fethi, and Ibrahim Dincer, eds. 2018. Exergy for A Better Environment and Improved Sustainability, Volume 1, Series title: Green Energy, Technology, Springer, Cham.

ME-574	Experimental Methods and Analysis	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To understand the importance of doing experiments in investigation of physical systems
CO2	To understand the importance of experimental data and its analysis
CO3	To understand various techniques and their selection for experimental investigations.

Statistics: Distributions, estimators, confidence levels, sample size, test of hypothesis, goodnessof- fit test Chauvenet’s criteria; Regression analysis, co-relations. Uncertainty analysis.Design of experiments.

Instruments: Specifications. Static and dynamic characteristics.Instruments for measuring distance, profile, pressure, temperature, velocity, flow rate, level, speed, force, torque, noise, chemical analyses.Estimation of systematic errors. Signal conditioning, data acquisition and analysis. Transducers, A-D & D-A converters, interfacing with computers and PLCs.

Control theory fundamentals: Steady state and transient response, Stability analysis Routh and Nyquist criteria, Root locus method. Sequence and programmable logic controllers.Hydraulic, pneumatic and electrical systems.

Laboratory: Calibration. Experiments related to heat transfer, fluid mechanics, thermodynamics and gas dynamics. Project on experiment design including drawings, wiring diagrams, selection of instruments and computer interfacing.Use of various controllers and actuators.Data management and presentation.

Books Recommended

1. Dally J E and Rilley W P, “Experimental Stress Analysis”, 3rd Edition, McGraw Hill, New Delhi (1991).
2. Dove R C and Adams P H, “Experimental Stress Analysis and Motion Measurement”, McGraw Hill, New York (1978).
3. Holister C S, “Experimental Stress Analysis”, 5th Edition, Cambridge University Press (1987).
4. Dally J E and Rilley W P, “Introduction to Photomechanics”, Prentice Hall Inc, NJ (1981).
5. Mubeen A, “Experimental Stress Analysis”, 1st Edition DhanpatRai and Sons, New Delhi (1997).

ME-575	**Gas Dynamics**	**(3 0 0 3)**

Course Outcomes: At the end of the course the student will be able to:

CO1	To understand the concept of different types of shocks and waves: normal and oblique, compression and expansion waves
CO2	To understand the compressible flow behavior with friction and heat transfer
CO3	To understand applications in measurement of subsonic and supersonic flows, wind tunnels, medical, aircraft and rocket propulsion
CO4	To provide introduction hydraulic turbines and pumps.

Recapitulation of fundamentals, introduction to numerical analysis of compressible flow. Oblique shocks, compression and expansion waves, Prandtl Meyer expansion. Interaction of shock waves and shock-boundary layer interaction. Flow with friction and heat transfer. Introduction to 1-D transient and 2-D compressible flow.Method of characteristics. Applications in measurement of subsonic and supersonic flows, wind tunnels, medical, aircraft and rocket propulsion. Introduction to hypersonic, high temperature flows and astro gas dynamics.fans.Surge, stall.Hydraulic turbines and pumps.

Books Recommended

1. Shepherd D G, “An Introduction to Gas Turbine”, Von Nastrand, New York (1949).
2. Stodola A, “Steam and Gas Turbines”, McGraw Hill Book Company, (1970).
3. Shapiro A M, “Dynamics and Thermodynamics of Compressible Fluids”, Ronald’s Press, New York (1953).
4. Benson R W, “Advanced Engineering Thermodynamics”, Pergamon Press, London (1975).
5. Cohen H, Rogers G F C and Saravanamuttoo H I H, “Gas Turbine Theory”, Orient Longman Limited, New Delhi (1996).

ME-576	**Gas Turbines and Jet Propulsion**	**(3 0 0 3)**

Course Outcomes: At the end of the course the student will be able to:

CO1	To understand the applications of turbines and jet propulsion and their energy requirements
CO2	To understand the various thermodynamics cycles used for cryogenics
CO3	To understand the concept of performance and combustion
CO4	Understand the principles of jet propulsion. Types of aircraft engines.

Introduction , Centrifugal fans Blowers and Compressors, Brayton cycle, regeneration and reheating cycle analysis., Axial flow fans and compressors, Elementary theory, degree of reaction, three dimensional flow, simple design methods, blade design, calculation of stage performance, overall performance and compressibility effects. Performance characteristics.
Axial flow turbines: elementary theory, vortex theory, choice of blade profile, pitch and chord estimation of stage performance, he cooled turbine, Combustion system: Form of combustion, important factors affecting combustion chamber design, combustion processes, combustion chamber performance, practical problem., Simple gas turbines: Components, characteristic, pressure losses, methods of improving part load performance, behaviour of gas turbines, Gas turbine rotors and stresses, Jet Propulsion -introduction - Early aircraft engines -Types of aircraft engines - Reciprocating internal combustion engines - Gas turbine engines - Turbo jet engine - Turbo fan engine - Turbo-prop engine. Aircraft propulsion theory: thrust, thrust power, propulsive and overall efficiencies.

Books Recommended

1. Cohen and Rogers, *Gas Turbines Theory*, Wesley Longman, 1996.
2. J.F. Lee, *Theory and design of stream and gas turbine*, McGraw Hill, 1954.
3. V. Ganesan, *Gas Turbine*, Tata McGraw Hill, 3rd edition, 2010.
4. R. Yadav, *Steam & Gas Turbines and Power Plant Engineering*, Central Publishing House, 2004.

ME-577	Measurements in Thermal Engineering	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand the concepts of errors in measurements, statistical analysis of data, regression analysis, correlation and estimation of uncertainty
CO2	Describe the working principles in the measurement of field and derived quantities
CO3	Analyze sensing requirements for measurement of thermo-physical properties, radiation properties of surfaces, and vibration
CO4	Understand conceptual development of zero, first and second order systems. Interpret International Standards of measurements (ITS-90) and identify internationally accepted measuring standards for measurands.

Basic concepts of measurements, Different types of errors in measurements,Statistics in Measurements, Principle of least square in measurements, Standard deviation, variance, Uncertainty in measurements, Influence coefficients, Linear regression, Least square fit, Goodness of fit, Correlation coefficient, Index of correlation, Error band, Multiple linear regression, Parity plot, Temperature measurements (Thermometry): Fundamental process of measurements, Thermometric thermometer(thermocouples), Thermoelectricity, Seebeck effect, Peltier effect, Thomson effect, Laws of Thermoelectric circuits, Common thermocouple pairs used in practice, Thermocouple junction in series, Measurement of temperature of a moving fluid using a thermo well, Temperature measurement in the solid, Measurement of Transient temperature, Resistance Thermometer, Measurements of temperature in Thermal radiation, Spectroscopic determination of gas temperature. Measurements of Heat Flux, Interferometry, Differential Interferometer, Pressure Measurements: Different pressure measurements, Vacuum measurements, Pirani gauge, Ionization gauge, Dynamic response of a U-tube manometer. Flow and velocity Measurements, Different methods of incompressible and compressible flow measurements, Pitot static tube, Hot wire anemometer, Ultrasonic method, Doppler effect, Vortex Shedding Flow meter, Laser Doppler velocity meter.Viscosity Measurement: Capillary method, Torque method, Saybolt viscometer, Pollution monitoring, Gas chromatography, NDIR analyzer.

Books Recommended

1. J.P.Holman, Experimental Methods for Engineers, McGraw Hill, 2001.
2. S.P.Venkateshan , *Measurements in Thermal Engineering*, Ane Books Pvt.Ltd.,
3. S.M.Yahaya, *Compressible Flow*, New Age International(p) Ltd., 2nd edition, 1998.

ME-578	Microscale Transport Phenomena	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understanding of the fundamentals of microscale fluid and heattransfer phenomena;
CO2	Understanding of dominant forces and their effects in microscale devices and systems
CO3	Understanding of the differences between the macro-and microscale fluid flows and heat transfer phenomena
CO4	Understanding of various microfluidic applications; and to explore new possible microfluidic applications in the numerous emerging fields.

Introduction: Origin, Definition, Benefits, Challenges, Commercial Activities, Physics of Miniaturization, Scaling Laws. Hydraulic Resistance and Circuit Analysis, Straight Channel of Different Cross-Sections, Channels in Series and Parallel.

Single-Phase Liquid Flow: Micro-Scale Fluid Mechanics: Intermolecular Forces, States of Matter, Continuum Assumption, Governing Equations, Constitutive Relations, Pressure Driven Liquid Micro-flow, Physics of Near-Wall Microscale Liquid Flows, Low *Re* Flows, Entrance Effects. Exact Solutions, Couette Flow, Poiseuille Flow, Stokes Drag on a Sphere, Time Dependent Flows.

Microscale Heat Conduction: Energy Carriers, Time and Length Scales, Scale Effects, Fourier's Law, Scale Effects of Thermal Conductivity.

Microscale Convection: Scaling laws, Temperature jump boundary condition, Convection in parallel plate channel flow and Couette Flow With and Without Viscous Dissipation, Heat Transfer in Micro Poiseuille Flows, Similarity and Dimensionless Parameters, Flow Boiling in Micro Channels, Nucleate and Convective Boiling, Saturated and Sub-Cooled Flow Boiling, Condensation Heat Transfer in Micro Channels, Micro Heat Pipes.

Single-Phase Gas Flow: Boundary Conditions, Wall Slip Effects and Accommodation Coefficients, Flow Analysis of MicroscaleCouette Flows, Pressure Driven Gas Micro-Flows with Wall Slip Effects, Effects of Compressibility, Introductory Concepts on Gas Flows in Transitional and Free Molecular Regimes.

Some Representative Applications of Micro-Scale Flows: Micro-Propulsion and Micro Nozzles, Micro-pumps, Micro-valves, Micro-flow sensors and Accelerometers, Micromixers, Micro-particle separators, Micro-reactors.

Books Recommended

1. P. Tabeling, Introduction to Microfluidics, Oxford University Press, 2005.
2. G. Karniadakis, A. Beskok, N. AluruMicroflows&Nanoflows: Fundamental andSimulation, Springer Publication, 2005.
3. J. Berthier and P. Silberzan, Microfluidics for Biotechnology, Artech House, 2006.
4. H. Bruus, Theoretical Microfluidics, Oxford University Press, 2008.

ME-579	Multi-Phase Flow and Heat Transfer	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand concept of multi phase flow and general governing equations
CO2	Understand physics involved in complex multiphase fluid flows
CO3	Analyse heat transfer and fluid dynamics involved in Pool and boiling
CO4	Evaluate film and dropwise condensation.

Introduction: Review of 1-D conservation equations in single phase flows; Governing equations for homogeneous, separated and drift-flux models.

Flow pattern maps: Horizontal and vertical systems; Simplified treatment of stratified, bubbly, slug and annular flows.

Pool Boiling: Thermodynamics of Pool boiling- onset of nucleation, heat transfer coefficients, critical heat flux, effect of sub-cooling.

Flow boiling: onset of nucleation, heat transfer coefficients, critical heat flux, effect of sub-cooling. Condensation- Film and dropwise condensation.

Books Recommended

1. G.B. Wallis, One dimensional two-phase flow, McGraw Hill, 1969.
2. J.B. Collier and J.R. Thome, Convective boiling and condensation, Oxford Science Publications, 1994.
3. Cebeci,T. and Bradshaw, P., Physical and Computational Aspects of Convective Heat Transfer, Springer-Verlag, 1984.
4. Cebeci,T. and Bradshaw,P., Momentum Transfer in Boundary Layers, McGraw Hill, 1977.
5. Patankar,S.V., Numerical Heat Transfer and Fluid Flow, McGraw Hill, 1980.

ME-580	Optimization Theory	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand basic mathematical concepts of optimization
CO2	Develop modeling skills necessary to describe and formulate optimization problems
CO3	To understand different methods of optimization and be able to suggest a technique for a specific problem
CO4	Develop skills necessary to solve and interpret optimization problems in engineering.

Basic Concepts, optimal problem formulation. Single variable optimization algorithms: bracketing, region elimination, point estimation, and gradient based methods, root finding, Multivariable optimization algorithms: unidirectional search, direct search methods, simplex search and gradient based methods. Constrained optimization algorithms : penalty function method, method of multipliers, sensitivity analysis, direct search for constrained minimization, linearized search techniques, feasible direction method, generalized reduced gradient method, and gradient projection method. Nontraditional optimization algorithms: Genetic algorithms, simulated annealing, and global optimization Computer programming practice for general design applications.

Books Recommended

1. S.S. Rao, *Engineering Optimization: Theory and Practice*,New Age International Publishers, 2006.
2. S.Bradley, A.Hax, T.Magnanti, *Applied mathematical programming*. Addison Wesley, 1977.
3. Rardin L. Ronald, *Optimization in operations research*, Prentice Hall. 1997.

4. Strang and Gilbert, Introduction to applied mathematics, Wellesley-Cambridge press, 1986.
5. K.Deb, *Optimization for engineering design: algorithms and examples.* Prentice Hall of India,New Delhi. 1996.
6. C.Balaji, Essentials of Thermal System Design and Optimization, Ane Books Pvt. Ltd., 2011.

ME-581	Photovoltaic Cell and its Applications	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To understand the physical principles of the photovoltaic (PV) solar cell and what are its sources of losses
CO2	To know the electrical (current-voltage and power-voltage) characteristics of solar cell, panel or generator and how the environment parameters influence it
CO3	To know the most important characteristics of the elements within a PV system, battery and charge controller, DC/DC converter, DC/AC converter (inverter) and loads
CO4	To understand the role of solar energy in the context of regional and global energy system, its economic, social and environmental implications, and the impact of technology on a local and global context
CO5	To know the main lines of research in the field of photovoltaic technology and solar energy.

Solar Radiation: Introduction, Measurement of Solar Radiation on Earth's Surface, Sun–Earth Angles, Solar Radiation on a Horizontal Surface, Solar Radiation on an Inclined Surface, Solar Cell Materials and Their Characteristics, Introduction, Doping, Fermi Level, p-n Junction, p-n Junction Characteristics, Photovoltaic Effect, Photovoltaic Material, Basic Parameters of Solar Cells, Effect of Cell Temperature on Cell Efficiency, Current Research on Materials and Devices, Silicon Processing.

PV Array Analysis: Introduction, Photovoltaic (PV) Module and Array, Theory and Construction, Series and Parallel Combinations, Balance of PV Array, Partial Shading of Solar Cell and Module, Maximum Power Point Tracker (MPPT), International Status of PV Power Generation.

Role of Batteries and Their Uses: Introduction, Fundamental Principles, Electro-chemical Action, Physical Construction, Discharge Characteristics, Charging Characteristics, Selection of PV Battery, Batteries Commonly Used for PV, Applications, Battery Installation, Operation and Maintenance, Battery Protection and Regulating Circuits Battery Simulation and Sizing,Battery Lifetime in a PV System, Charging State of PV-powered Storage Batteries, General Terms.

Thermal Modelling of Hybrid Photovoltaic/Thermal (PV/T) Systems: Introduction, PV/T Air Collectors, Hybrid Air Collector, Double-pass PV/T Solar Air Collector, Thermal Modelling of PV/T Air Collector, Covered by Glass-to-Tedlar Type PV Module, Thermal Modelling of PV/T Air Collector, Covered by Glass-to-Glass Type PV Module, Testing of the Solar Air Collector, PV/T Solar Water Heater, PV/T Solar Distillation System, Active PV/T Distillation System, PV/T Solar Dryers,Statistical Analysis

Energy and Exergy Analysis: Energy Analysis, Energy Matrices,Embodied Energy, Embodied Energy of PV Module (Glass-to- Glass) Balance of System (BOS), Analysis of Embodied Energy and EPBT of PV/T Solar Systems, Energy Pay-back Periods of Roof-mounted Photovoltaic Cells, Exergy Analysis, Importance of Exergy, Exergy of a Process, Exergetic Analysis of Flat-plate Collector, Exergetic Analysis of PV/T Systems.

Economic Analysis: Introduction, Cost Analysis, Cash Flow, Cost Comparisons with Equal Duration, Cost Comparisons with Unequal Duration, Analytical Expression for Payout Time, Net Present Value, Benefit-Cost Analysis, Internal Rate of Return, Effect of Depreciation, Cost Comparisons of Solar Dryers with Duration.

Case Studies of PV/T Systems: Introduction, Different types of case study Grid-connected Building Integrated, Photovoltaic System (BIPV), PV-integrated Water-pumping Application, Simulation of an Existing BIPV System for Indian Climatic Conditions etc.

ME-582	Refrigeration Systems and Components Design	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To know about the design of various refrigeration system components
CO2	To learn some different refrigeration systems
CO3	To understand the components of vapor compression systems and other types of cooling systems
CO4	To learn about design of cold storages, mobile refrigeration system and various commercial applications of refrigeration.

Introduction to various components.Thermal design of reciprocating, centrifugal and screw compressors.Capacity control methods.Thermal design of different evaporators–DX, flooded, etc.Thermal design of condensers–water-cooled and air-cooled.Sizing of capillary. Selection of expansion valves and other refrigerant control devices. Components balancing. Testing and charging methods. Design of absorber and generator of vapor absorption systems. Design of cold storages, mobile refrigeration, refrigerators, commercial appliances.

Books Recommended

1. Arora C P, “Refrigeration and Air Conditioning”, 19th Edition, Tata McGraw Hill, Delhi, 1985.
2. Pradad M, “Refrigeration and Air Conditioning”, 2nd Edition, New Age International Private Limited, Delhi (2002).
3. Dossat, R J, “Principles of Refrigeration”, 4th Edition, Pearson Education (Singapore), India, 2002.
4. Mcquiston F G, Parker J D and Spilter J D, “Heating, Ventilating, and Air Conditioning”, 5th Edition, John Wiley and Sons Inc, New York, 2001.
5. Jordan and Prister, “Refrigeration and Air Conditioning”, Prentice Hall of India, 1998.

ME-583	Renewable Energy	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To explain the basic principles of various renewable energy conversion processes and devices used therein
CO2	To identify various parameters that influences the performance of renewable energy devices/processes
CO3	To undertake the field projects in the area of solar thermal, solar PV, wind, biomass, ocean energy, geothermal etc.
CO4	To identify suitable renewable source and technology for a given requirement
	To develop the integrated renewable energy technology for decentralized power sector.

Need of sources of renewable energy, Introduction to different sources of renewable energy, e.g., Solar Energy, Wind Energy, Bio-mass, Geothermal Energy, Ocean energy, Solar Energy and Applications , Basic concepts, , Flat plate and concentrating collectors, applications such as Air Heater, water heaters, thermal energy storages, photo: voltaic cell, Wind Energy, Sources and potentials, horizontal and vertical axis windmills, performance characteristics, Augmentation of wind power, Betz criteria, Bio-Mass: Principles of Bio-mass conversion, Anaerobic/Aerobic digestion, types of Bio-gas digesters, Combustion characteristics of bio-gas and its different utilizations, Geothermal Energy: Resources, methods of harnessing energy, Ocean Energy: Principles utilization, thermodynamic cycles, tidal and wave energy, potential and conversion technique.

Books Recommended

1. John A. Duffie and William A. Beckman, *Solar Engineering forThermal Process*, Wiley and Sons, 2013.
2. Tiwari and Ghoshal, *Renewable Energy Sources*, Narosa Publication, 2007.
3. K.Mittal, *Non-conventional energy systems*, Wheeler Publ House, 2003.
4. S.P.Sukhatme, *Solar Energy- Principles of Thermal Collection and Storage*, TMH, 2005.
5. H.P. Garg, *Solar Energy*, TMH, 1997.
6. D.P.Kothari and K.C.Singhal, *Renewable Energy Sources and emerging technologies*, PHI Learning private Ltd., 2nd edition, 2012.

ME-584	**Solar Passive Design and Sustainable buildings**	**(3 0 0 3)**

Course Outcomes: At the end of the course the student will be able to:

CO1	Understanding the basic principles and fundamentals of mechanical engineering in the building integrated passive design
CO2	To understand the interrelation of engineering and building science for sustainable development in built environment
CO3	To provide a bird eye view of Indian building compliance codes and energy efficiency measures for sustainable buildings and building integrated systems.

Introduction: Heating and cooling load of buildings: elements of heating and cooling load, load reduction approaches.

Passive heating and cooling in buildings:Direct and indirect solar passive heating systems; solarium, trombe wall, trans-wall, thermal mass, courtyard effect, wind tower design, earth air tunnel system, evaporative cooling, radiative cooling.

Green and Sustainable buildings: Concept of green buildings, features of green building rating systems in India, indoor environment issues for green buildings, Green home rating system, Concept of Net zero energy building.
Building Energy Codes: Energy Conservation Building Code: requirements of code, applicability, compliance options: prescriptive, trade-off, whole building performance methods.

Books Recommended

1. Passive and low energy cooling of building by Baruch Givoni (John Willey & Sons).
2. Advances in Passive Cooling by MatheousSantamouris (Earthscan, London).
3. Passive Building Design: A handbook of natural climate control (N K Bansal, G Hauser, GMinke).
4. Energy Conservation Building Code (ECBC, 2016), Bureau of Energy Efficiency, India.

ME-585	**Thermal Behaviour of Advanced Materials**	**(3 0 0 3)**

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand various strengthening mechanisms of materials
CO2	Learn about thermal behaviour of advanced materials like Ceramics, Composites, Shape memory alloys, Metglasses, and Nanostructured Materials
CO3	Understand accounting for creep in development of technologically important materials such as long-fibre composites and discontinuously reinforced composites

CO4	Learn about heat treatment mechanisms, Conductivity and Internal thermal resistance of composites.

Basic Information about the Material, Elastic behavior of materials, concept of engineering and true stress and true strain, tensile property, yield point phenomenon & elastic modulus. Heat Treatment Processes, Strengthening Mechanisms of Materials, Basics of Thermal, Optical, Electrical and Magnetic Properties of Materials, Concepts of Creep, Fatigue, Fracture and Corrosion, Introduction to Ceramics, Composites, Shape Memory Alloys, Metglasses, and Nanostructured Materials, Thermal Behaviour of Composites,Thermal expansion and thermal stresses: Thermal stresses and strains, Thermal expansivities, Thermal cycling of unidirectional composites, Thermal cycling of laminates, Creep: Basics of matrix and fibrebehaviour, Axial creep of long-fibre composites, Transverse creep and discontinuously reinforced composites,Thermal Conduction: Heat treatment mechanisms, Conductivity of composites, Internal thermal resistance.

Books Recommended

1. T. E. Reed-Hill & R Abbaschian, *Physical Metallurgy Principles*, Thomson.
2. L.H. Van Vlack, *Elements of Materials science & Engineering*, Addison Wesley Pub. Company,
3. Hull and Clyne, *An Introduction to Composite Materials*, Cambridge University Press,
4. Diwan and Bhradwaj, *Nano Composites*, Pentagon Press, New Delhi.
5. William D CallisterJr, *Materials Science and Engineering*, John Wiley & Sons, Inc.
6. G.E. Dieter, *Mechanical Metallurgy*, McGraw-Hill, London.
7. V.Raghvan, *Materials Science and Engineering*, Prentice Hall of India.

ME-586	Turbomachinery	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To understand various devices used for power production and transmission
CO2	To understand the working principles and analysis of various turbo-machines
CO3	To understand various operation difficulties involved in turbo-machines
CO4	To understand various techniques to improve the performance of various turbo-machines.

Introduction, Classification of turbo machinery.Application of Time Temperature diagram – theorem in turbo machinery.Incompressible fluid flow 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 airfoil section – 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 impeller channel – flow in the discharge casing pump and compressor characteristic, Radial flow turbines – inward flow turbines for compressible fluids – inward flow hydraulic – velocity and flow coefficients – gas turbine blading – Kaplan turbine – pelton wheels.

Books Recommended

1. Lee, *Theory and Design of Steam and Gas Turbine*, McGraw Hill, 1954
2. S.M.Yahya, *Turbines, Compressions & Fans*, Tata McGraw Hill. 1983.
3. J.Lal, Hydraulic Machines, Metropolitan Books Co. Ltd, N.Delhi, 1956.

ME-587	Waste Heat Utilization and Polygeneration	(3 0 0 3)

Course Outcomes: At the end of the course the student will be able to:

CO1	To apply the knowledge of power generation configurations for power and process heating to suit the waste heat recovery
CO2	To estimate performance of integrated energy system with suitable applications. To develop the layouts for the desalination and cooling integration
CO3	To apply the knowledge of energy storage for poly-generation. To design the heat exchangers for poly-generation with waste heat recovery
CO4	To justify the poly-generation plants with the thermos-economic evaluation.

Power generation: Review of Thermodynamics, Indian potentials and scenario for power generation, cogeneration and polygeneration. Methods of improving the current technologies.Power cycles and their limitations, organic Rankine cycle, areas of major losses.Micro turbine systems, decentralized power generation, direct conversion technologies – Thermoelectric generators, Thermoionic conversion, Thermo-PV, MHD. Combined cycle, combined gas turbine-steam turbine power plant, heat recovery steam generators.Heat recovery vapor generators.Thermodynamic cycles for low temperature application.

Cogeneration: Topping cycle cogeneration. Industrial Examples: Process heating in sugar plants, paper and other industries. Bottoming cycle: Waste Heat Boilers, Metal industries, cement plants and potential in power plants. Case studies on cogeneration.

Desalination and Cooling: Desalination- basics. Types of desalination systems. Vapor absorption refrigeration system – concept - working – types. Case studies.

Trigeneration: Multi product polygeneration- multi fuel polygeneration - Case studies on trigeneration and polygeneation systems – Performance calculations. Efficiency of polygeneration compared to stand-alone production.

Waste heat recovery: A case study for heat recovery - potential in India. Special heat exchangers for waste heat recovery, Synthesis of heat exchanger network. Pinch technology, Selection of pinch temperature, stream splitting, process retrofit, insulation, fins, effective use of heat pumps and heat engines, heat pipes.

Design of heat recovery systems: Effectiveness, Types of heat exchangers – LMTD- effectiveness-NTU methods. Recuperative, Regenerative, run-around coils.

Energy Storage: Pumped hydro, Compressed air, Flywheel, Superconducting magnetic storage. Smart buffers (batteries, hot and cold thermal energy storage, pure water reservoirs, etc).

Techno-economics: Investment cost – economic concepts – measures of economic performance – procedure for economic analysis – examples – procedure for optimized system selection and design – load curves – sensitivity analysis – regulatory and financial frame work for cogeneration and waste heat recovery systems,Thermoeconomic optimization of polygeneration systems.

Books Recommended

1. Eastop, T.D. & Croft D.R, “Energy efficiency for engineers and Technologists”, 2nd edition, Longman Harlow, 1990.
2. EDUCOGEN – The European Educational tool for cogeneration, Second Edition, 2001.
3. Osborn, peter D, “Handbook of energy data and calculations including directory of products and services”, Butterworths, 1980.
4. Charles H.Butler, Cogeneration, McGraw Hill Book Co., 1984.
5. Horlock JH, Cogeneration - Heat and Power, Thermodynamics and Economics, Oxford, 1987.
6. Institute of Fuel, London, Waste Heat Recovery, Chapman & Hall Publishers,London, 1963.
7. Seagate Subrata, Lee SS EDS, Waste Heat Utilization and Management, Hemisphere, Washington, 1983.
8. Srinivas, T. Shankar Ganesh N and Shankar R., 2019, Flexible Kalina Cycle Systems, Taylor and Francis Publishers, CRC press, ISBN: 9781771887137.