Curriculum & Syllabi

M. Tech. Degree Programme

ENERGY ENGINEERING AND MANAGEMENT

(with effect from Academic Year 2018-2019)

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Vision of the Institute
International standing of the highest calibre

Vision of the Department
To impart nationally and internationally recognized education in Mechanical Engineering, leading to well-qualified engineers who are innovative contributors to the profession and successful in advanced studies and research.

Mission of the Institute
To develop high quality technical education and personnel with a sound footing on basic engineering principles, technical and managerial skills, innovative research capabilities, and exemplary professional conduct to lead and to use technology for the progress of mankind, adapting themselves to changing technological environment with the highest ethical values as the inner strength.

Mission of the Department
To offer high quality graduate and post graduate programs in the fields of Mechanical Engineering and to prepare students for professional career and higher studies promoting excellence in teaching, research, entrepreneurship, collaborative activities with ethical values, making positive contributions to the society.

M.Tech. in Energy Engineering and Management

PROGRAM EDUCATIONAL OBJECTIVES

PEO 1: To train students with in-depth and advanced knowledge to become highly-skilled professionals in the areas of energy engineering and related fields capable of identifying, analysing and solving practical engineering problems.

PEO 2: To enable graduates to carry out innovative and independent research work in academia/ industry to develop energy efficient systems and processes and to disseminate the knowledge.

PEO 3: To prepare the students to exhibit a high level of professionalism, integrity, environmental and social responsibility, and life-long independent learning ability.

PROGRAM OUTCOMES

PO1: An ability to independently carry out research/ investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area as per the Energy Engineering and Management programme. The mastery should be at a level higher than the requirements in the appropriate bachelor programme.

PO4: An ability to acquire and share in-depth knowledge in the area of energy engineering and management.

PO5: An ability to analyse complex problems in the field of energy engineering critically and arrive at optimal solutions.

PO6: An ability to use modern computer/software tools to model and analyse problems related to energy engineering and management.

Curriculum for M. Tech. in Energy Engineering and Management

(2018 Admission)

Semester-1					
Code	**Title of Course**	**L**	**T**	**P/S**	**C**
MA6001D	Mathematical Methods	3	0	-	3
ME6401D	Advanced Energy Conversion Systems	3	0	-	3
ME6402D	Alternative Energy Technology	3	0	-	3
	Elective-1	3	0	-	3
	Elective-2	3	0	-	3
ME6491D	Computational Lab	--	0	3	2
	Total	**15**	**0**	**3**	**17**

Semester-2					
Code	**Title of Course**	**L**	**T**	**P/S**	**C**
ME6411D	Fluid Flow & Heat Transfer in Energy Systems	3	0	-	3
ME6412D	Design & Analysis of Energy Systems	3	0	--	3
ME6413D	Industrial Energy Conservation	3	0	-	3
	Elective-3	3	0	-	3
	Elective-4	3	0	-	3
ME6492D	Energy Engineering Lab	--	0	3	2
ME6493D	Seminar/Mini Project	--	0	2	1
	Total	**15**	**0**	**5**	**18**

Semester-3

Code	**Title of Course**	**C**
ME7494D	Project work (Phase-I)	12
	Total	**12**

Semester-4

Code	**Title of Course**	**C**
ME7495D	Project work (Phase-II)	13
	Total	**13**

L: Lecture, T: Tutorial: P, Practical, S: Seminar, C: Credit

Total Credits: 60

Stipulations

1. A minimum of 60 credits (Maximum credits permitted 62) have to be earned for the award of M. Tech. degree in this programme.
2. Students may audit the course on '*Communicative English*' in the first or second semester of the programme and this course shall not be indicated in the grade card.
3. For elective courses, students may choose any PG level course offered in the Institute with the approval from the Programme Coordinator.
4. It is desirable for students to undergo *Two Months* Industrial Training/Internship during summer vacation.
5. Students are permitted to audit course/s in the Third and Fourth Semesters of the programme. Only a maximum of two audited courses for which a minimum pass (P) grade secured shall be recorded in the grade card.

Credit distribution	
Curricular composition	**Credits**
Theory courses	30
Laboratory courses	4
Seminar	1
Project works	25
Total credits	**60**

List of Electives

Stream-specific Elective Courses			
Sl. No.	**Code**	**Title**	**C**
1	ME6421D	Direct Energy Conversion Systems	3
2	ME6422D	Energy and Environment	3
3	ME6423D	Integrated Energy Systems	3
4	ME6424D	Energy policies for sustainable development	3
5	ME6425D	Optimal design of heat exchangers	3
6	ME6426D	Fluidized bed systems	3
7	ME6427D	Heat pump technology	3
8	ME6428D	Design of Solar Thermal Systems	3
9	ME6429D	Energy efficient buildings	3
10	ME6430D	Biofuel Production and Applications	3
11	ME6431D	Micro-channel flow and mixing analysis	
11	ME6432D	Advanced air breathing propulsion	3
12	ME6433D	Cryogenic rocket propulsion systems	3
13	ME6434D	Environmental engineering and pollution control	3
15	ME6435D	Hydrogen production, storage and transportation	3
16	ME6436D	Hydrogen energy conversion technology	3
17	ME6437D	Energy modeling, economics and project management	3
18	ME6438D	Hydropower Systems	3
19	ME6439D	Information technology in energy management	3
20	ME6440D	Thermodynamic Properties Relations and Exergy Analysis	3

Other suggested Elective Courses			
Sl. No.	**Code**	**Title**	**C**
1	ME6113D	Accounting and Finance for Management	3
2	ME6221D	Thermal Environmental Engineering	3
3	ME6222D	Design of Heat Transfer Equipment	3
4	ME6224D	Aerodynamics	3
5	ME6225D	Cryogenic Engineering	3
6	ME6227D	Analysis of Internal Combustion Engines	3
7	ME6228D	Multiphase Flow	3
8	ME6235D	Advanced Computational Fluid Dynamics	
9	ME6305D	Industrial Automation and Robotics	3
10	ME6322D	Computer Graphics	3
11	ME6329D	Design of Experiments	3
12	ME6612D	Finite Element Methods and Applications	3

Syllabi for M. Tech. Energy Engineering and Management
(2018 Admission onwards)

MA6001D MATHEMATICAL METHODS

Pre-requisites:Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:
CO1. Learn Vector spaces, Inner product spaces, linear transformations and construct orthonormal basis.
CO2. Find power series solutions of ODEs, study Legendre, Bessel equations, learn Frobenius method and Sturm-Liouville problem.
CO3: Use Lagrange method, Charpit's method, Jacobi method to find the solution of first order PDEs and use method of separation of variables to solve linear second order PDEs.
CO4: Learn coordinate transformations, covariant, contravariant and mixed tensors, conjugate tensor, Quotient law, Christoffel's symbols and covariant derivative.

Module 1: (10 hours)
Linear Algebra:vector spaces, subspaces, basis, dimension, inner product spaces, Gram-Schmidth process, linear transformations, range and kernel, isomorphism, matrix of transformations and change of basis.

Module 2: (9 hours)
Series Solutions of ODE and Sturm-Liouville Theory: power series solutions about ordinary point, Legendre equation and Legendre polynomials, solutions about singular points; the method of Frobenius, Bessel equation and Bessel functions; Sturm-Liouville problem and generalized Fourier series.

Module 3: (10 hours)
Partial Differential Equations: first order PDEs, linear equations, Lagrange method, Cauchy method, Charpits method, Jacobi method; second order PDEs: classification, method of separation of variables, formulation and solution of wave equation, heat equation and Laplace equation.

Module 4: (10 hours)
Tensor Calculus: spaces of *n*-dimensions coordinate transformations, covariant, contravariant and mixed tensors, fundamental operation with tensors, quotient law, the line element and metric tensor, conjugate tensor, Christoffel's symbols, covariant derivative.

References:

1. D. C. Lay,*Linear Algebra and its Applications*.Addision Wesley,2003.
2. F. G. Florey,*Elementary Linear Algebra with Application*. Prentice Englewood, 1979.
3. W. W. Bell,*Special Functions for Scientists and Engineers*. Dover Publications,2004.
4. I.Sneddon, *Elements of Partial Differential Equations*. McGraw Hill International, 1985.
5. B. Spain,*Tensor Calculus*, Oliver and Boyd,1965.
6. K.SankaraRao,*Introduction to Partial Differential Equations*, 3rd ed. Prentice-Hall, 2010.
7. S. L. Ross,*Differential Equations*, 3rd ed. JohnWiley&Sons, 2004.
8. L.A.Pipes and L.R. Harwill, *Applied Mathematics for Engineers and Physicists*. McGraw Hill, 1971.
9. M.A. Akivis and V.V. Goldberg, *An Introduction to Linear Algebra and Tensors*. Dover Publications,1997.
10. U. C. De, A. A. Shaikh, J. Sengupta, *Text book of Tensor Calculus and Differential Geometry*, 2nd ed. Alpha Science International, 2007.

ME6401D ADVANCED ENERGY CONVERSION SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Knowledge of various solid, liquid and gaseous fuels, their characterization techniques with focus on fossil and nuclear fuels
CO2: Design and analyse various energy conversion techniques emphasizing on combustion processes and efficiency
CO3: Analyse nuclear reactions and to execute thermal design of nuclear reactors
CO4: Heat removal and strategies to protect the environment from nuclear emissions

Module 1: (14 hours)

Classification of energy sources - Utilization, economics and growth rates - Fossil fuels, nuclear fuels - Combustion calculations, Excess air coefficient, Adiabatic flame temperature - Conventional thermal power plant design and operation - Superheat, reheat and regeneration –Co-generation, Tri-generation, Other auxiliaries of thermal plant - High-pressure boilers - Steam generator control.

Module 2: (12 hours)

Gas turbine and combined cycle analysis – Intercooling, reheating and regeneration-gas turbine cooling - design for high temperature - Combined cycles with heat recovery boiler – Combined cycles with multi-pressure steam - STAG combined cycle power plant - Influence of component efficiencies on cycle performance, Gas Turbine applications.

Module 3: (13 hours)

Nuclear energy conversion - Chemical and nuclear equations - Nuclear reactions -Fission and fusion - Energy from fission and fuel burn-up - Radioactivity – Neutron energies - Fission reactor types - Nuclear power plants - Fast breeder reactor and power plants - Production of nuclear fuels.
Fuel rod design - Steam cycles for nuclear power plants - reactor heat removal – Coolant channel orificing - Core thermal design - Thermal shields - Fins in nuclear plants – Core thermal hydraulics - Safety analysis - LOCA - Time scales of transient flow and heat transfer processes.

References:

1. M. M. El-Wakil: *Power Plant Technology*, McGraw Hill, 1985
2. A. W. Culp Jr: *Principles of Energy Conversion*, McGraw Hill, 2001
3. H. A. Sorensen: *Energy Conversion Systems*, J. Wiley, 1983
4. T. F. Morse: *Power Plant Engineering*, Affiliated East West Press, 1978
5. M. M. El-Wakil*: Nuclear Power Engineering*, McGraw Hill, 1962
6. R. H. S. Winterton: *Thermal Design of Nuclear Reactors*, Pergamon Press, 1981
7. R. L. Murray: *Introduction to Nuclear Engineering*, Prentice Hall, 1961

ME6402D ALTERNATIVE ENERGY TECHNOLOGY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1:Identify the nature and availability of different alternative energy sources
CO2: Describe the different energy conversion systems based on alternative energy
CO3: Model the energy conversion and evaluate useful energy from alternative energy conversion devices
CO4: Analyse the performance of alternative energy conversion devices

Module 1: (14 hours)
Solar energy: The Sun, Production and transfer,Availability and limitations;Sun-Earth angles;Sun path diagram; Solar radiation, Extraterrestrial solar radiation, Terrestrial irradiation; solar radiation on horizontal and inclined planes; Measuring techniques and estimation of solar radiation; Solar energy collectors: stationary collectors-Flat plate collectors, Compound parabolic collectors,Evacuated tube collector; Sun tracking concentrating collectors-Parabolic trough collectors, Fresnel collectors, Parabolic dish collectors, Heliostat field collectors; Thermal analysis of flat plate collectors: Absorbed solar radiation, Collector energy analysis, Temperature distribution, Collector efficiency factor; Thermal analysis of air collector.

Module 2: (13 hours)
Solar energy systems: Passive systems, Active systems; Energy storage: Sensible heat storage, Liquid media storage, Solid media storage, Dual media storage, Phase change energy storage, Storage capacity,Other storage methods; Solar dehumidification: Design, performance and applications; Combined solar heating and cooling systems; Special topics on solar energy.
Energy from biomass: Sources of biomass, Different species, Conversion of biomass into fuels; Energy through fermentation: Pyrolysis, gasification, combustion; Aerobic and anaerobic bio-conversion:Types of biogas plants: Design and operation.

Module 3: (12 hours)
Wind energy: availability; Turbine types: Horizontal axis machines, vertical axis machines, Concentrators; Linear momentum and basic theory: Energy extraction, Axial force, Torque, Drag machines; Dynamic matching: optimal rotation rate, tip speed ratio, Extensions for linear momentum theory; Blade elementary theory; Geothermal energy – Availability, system development and limitations – Ocean thermal energy conversion – Wave and tidal energy – Scope and economics – Introduction to integrated energy systems.

References:

1. J.A. Duffie and W.A. Beckman: *Solar Engineering of Thermal Processes*, J. Wiley, 2013
2. A.A.M. Saigh (Ed): *Solar Energy Engineering*, Academic Press, 1977
3. F. Kreith and J.F. Kreider: *Principles of Solar Engineering*, McGraw Hill, 1978
4. G.N. Tiwari: *Solar Energy-Fundamentals, Design, Modelling and Applications*, Narosa Publishers, 2002
5. S.A.Kalogirou: *Solar Energy Engineering Processes and Systems*, Elsevier, 2009
6. J.Twidell and T. Weir: *Renewable Energy Resources, Taylor& Francis,* 2006
7. K.M. Mittal: *Non-conventional Energy Systems-Principles, Progress and Prospects*, Wheeler Publications, 1997
8. G.D. Rai: *Non-conventional Energy Sources*, Khanna Publishers, 2003

ME6491D COMPUTATIONAL LABORATORY

Pre-requisites: nil

L	T	P	C
0	0	3	2

Total hours: 39

Course Outcomes:

CO1: Modeling of fluid and heat transfer energy systems;
CO2: Numerical discretization of ordinary/partial differential equations;
CO3: Solve heat transfer and fluid flow complex problems using software;
CO4: Infer the technical insights of various problems

Modeling a physical problem; Numerical descritization; Usage of various numerical schemes; Application in energy systems - Fluid flow in pipes/ducts; flow over flat plates – boundary layers; flow over cylinders; conduction heat transfer in slabs; free and forced convection heat transfer in pipes - flat plates – cylinders.

List of computational experiments

1. Roots of algebraic and transcendental equations
2. Solution of simultaneous algebraic equations
3. Numerical integration and differentiation
4. Numerical solution of ODEs: Initial value problems and Boundary value problems
5. Numerical solution of PDEs: Initial value problems and Boundary value problems
6. Compare the accuracies of different numerical schemes
7. Velocity profile of a fully developed flow in a pipe using software and analytical comparison
8. Velocity profile of a boundary layer over a flat plate using software and analytical comparison
9. Flow past cylinder using software and analytical comparison
10. Temperature distribution in a slab at given boundary conditions and analytical comparison

References:

1. S.C. Chapra and R.P. Canale: *Numerical Methods for Engineers*, 2e, McGraw Hill, 1990
2. Y. Jaluria: *Computer Methods for Engineers*, 2e, McGraw Hill, 1990
3. J.M.L. Smith and J.C. Wolford: *Applied Numerical Methods for digital computation*, Harper & Row, 1977

ME6411D FLUID FLOW AND HEAT TRANSFER IN ENERGY SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1:Formulate the conservation equations in different frames of reference and in different approaches
CO2: Model the conduction heat transfer in different practical situations and rate evaluation
CO3: Model the convective heat transfer in different practical situations and rate evaluation
CO4: Model the radiation heat transfer in different practical situations and rate evaluation

Module 1: (11 hours)

Review of fundamental concepts: continuum, control volume, Eulerian and Lagrangian methods of description of fluid flow; Reynolds transport equation; integral and differential forms of continuity, momentum, and energy equations, Navier-Stokes equations and boundary conditions; Non-dimensionalization of equations and order of magnitude analysis, dimensionless parameters and their significance; classification of flows based on the characteristic Reynolds number; equations for low and high Reynolds number flows.

Module 2: (16 hours)

Differential formulation of general heat transfer problems - Types of boundary conditions – Homogeneous equations and boundary conditions. Conductive heat transfer in energy systems - Practical examples including nuclear reactors, solar thermal collectors, heat exchangers, energy storage systems, etc.
Convective heat transfer in energy systems - Differential formulation of heat and fluid flow - Discussion on relevant boundary conditions - Convection models for solar flat plate collectors, solar ponds, boiler tubes, etc.

Module 3: (12 hours)
Review of thermal radiation - Shape factor algebra - Modeling of enclosure – Radiation in non-absorbing media - Radiation exchange in absorbing media - Radiation from gases, vapours and flames.

References:

1. Muralidhar. K. and Biswas, G., Advanced Engineering Fluid Mechanics, Third Edition, Narosa Publishing House, 2015
2. D. Poulikakos: Conduction Heat Transfer, Prentice Hall, 1994
3. V.S. Arpaci: Conduction Heat Transfer, AddisionWesly, 1996
4. H.S. Carslaw and J.C. Jaeger: Conduction of Heat in Solids, Oxford University Press, 1959
5. A. Bejan: Convection Heat Transfer, J. Wiley, Fourth Edition, 2013
6. M.F. Modest: Radiative Heat Transfer, Academic Press,Third Edition, 2013

ME6412D DESIGN AND ANALYSIS OF ENERGY SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Design energy systems for engineering applications and model their performance (like turbo machines, heat exchangers, HVAC systems, etc.).
CO2: Analyze systems (particularly, energy systems) as a whole under design and off-design operating conditions.
CO3: Improve and optimize the system performance, especially, with respect to energy systems.

Module 1: (13 hours)

Engineering design fundamentals - Designing a workable system - Economic evaluation - Fitting data and solving equations - Heat exchanger design calculations - Evaporators and condensers temperature-concentration-pressure characteristics of binary solutions - Rectifiers - Cooling towers -Pressure drop and pumping power.

Module 2: (11 hours)

Pump characteristics - Manufacturer's specifications - Relations among performance characteristics - Pump system operation - Cavitation prevention - Other system considerations, Fans and nozzles - Basics of Second law analysis in heat and fluid flow - Applications in thermal design.

Module 3: (15 hours)

Modeling and simulation principles - Hardy-Cross method - Multi-variable, Newton-Raphson simulation method - Simulation of a gas turbine system - Simulation of a VA refrigeration system - Simulation using differential equations - Mathematical modeling of thermodynamic properties - Steady state simulation of large systems – Simulation of dynamic systems - Design optimization - Knowledge based system design.

References:

1. A. Bejan: *Thermal Design and Optimization*, John Wiley, 1995
2. Y. Jaluria: *Design and Optimization of Thermal Systems*, 2e, CRC Press, 2008
3. W.F. Stoeker: *Design of Thermal Systems*, 3e, McGraw Hill, 1989
4. B.K. Hodge: *Analysis and Design of Energy Systems*, Prentice Hall, 1990
5. R.F. Boehm: *Design Analysis of Thermal systems*, John Wiley, 1987
6. Yunus A. Cengel: *Thermodynamics: An Engineering approach*, McGraw Hill, 1994

ME6413D INDUSTRIAL ENERGY CONSERVATION*

Pre-requisites: NIL

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Perform energy audit of industrial systems
CO2: Analyze the energy conversion efficiencies and specific energy consumption of industrial systems
CO3: Analyze the performance of industrial energy systems based on exergy
CO4: Perform techno-economic analysis of industrial energy systems

Module 1: (13 hours)
Efficiency and sustainability in industrial energy systems, current scenario; energy auditing: methodology, instruments for energy audit, analysis of plant data and systematic reporting, application of mass and energy balance; steam systems: steam generator performance, excess air control, steam distribution and use of steam traps; thermal Insulation and refractories, energy conservation in furnaces; waste heat recovery options.

Module 2: (13 hours)
Cogeneration: different schemes, performance assessment; energy conservation in HVAC systems; exergy analysis of thermal systems: reversible work and exergy destruction, exergy transfer and exergy balance; exergy efficiency of thermal systems; thermo-economics and pricing of utilities; heat exchanger networking: concept of pinch, energy targeting, composite curves, problem table algorithm.

Module 3: (13 hours)
Electrical energy management: overall structure of electrical systems, supply and demand side management, economic operation; reactive power, power factor correction and capacitor sizing; transformer loading and efficiency analysis; feeder loss evaluation; energy efficient lighting schemes; types and operating characteristics of electric motors: energy efficient control and starting, load matching, motor selection; Industrial drives and control schemes, variable speed drives and energy conservation schemes; energy conservation in pumps and fans; case studies.

References:

1. A. Thumann, T. Niehus, and W. J. Younger, *Handbook of Energy Audits*, 9th ed. CRC Press, 2013.
2. S. Doty and W. C. Turner, *Energy Management Handbook*, 6th ed. Fairmont Press, 2007.
3. M. H. Chiogioj, *Industrial Energy Conservation*, Marcel Dekker, 1979.
4. W. F. Kenney, *Energy Conservation in the Process Industries*, Academic Press, 1984.
5. Z. K. Morvay and D. D. Gvozdenac, *Applied Industrial Energy and Environmental Management*, Wiley, 2008.
6. M. Kanoglu, Y. A. Cengel, and I. Dincer, *Efficiency Evaluation of Energy Systems*, Springer, 2012.
7. I. C. Kemp, *Pinch Analysis and Process Integration: A User Guide on Process Integration for the Efficient Use of Energy*, 2nd ed. Elsevier, 2007.
8. IEEE, *IEEE Bronze Book: IEEE Standard 739-1984 - Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities,* IEEEPublications, 1996.

PS: This subject is to be handled by 50:50 sharing basis between MED & EED

ME6492D ENERGY ENGINEERING LABORATORY

Pre-requisite: Nil

L	T	P	C
0	0	3	2

Total Hours: 39

Course Outcomes:

CO1: Knowledge to develop rectifying solutions of existing energy systems or solutions to new problems.
CO2: Design and fabricate energy systems as per the requirement based on the theory and principles learnt.
CO3: Analyse the performance of existing energy systems and modernize the designs using the various tools learned.

Fabrication, maintenance and experimentation on heat exchangers, refrigeration system, heat pipes, and solar thermal systems like air heater, water heater, heat pump, solar still etc. Experimentation on Biomass gasifiers, Fluidised bed system, waste heat recovery system and wind turbine.

List of Suggested Experiments on Energy Systems

1. Performance study on Heat Exchangers
2. Performance study on Refrigeration Systems
3. Performance study on heat pumps
4. Performance study on Heat pipes
5. Performance of Energy Efficient Chulah
6. Experiment on Wind Energy System
7. Experiment on Solar PV System
8. Performance of Solar Water heater.
9. Experimentation on Solar Air Heaters
10. Performance of Solar Still
11. Performance study on Biomass Gasifiers
12. Experiment on Fluidized Bed System
13. Experiment on Waste Heat Recovery Systems

References

1. S. P. Sukhatme and J. K. Nayak, *Solar Energy*, 4th ed. McGraw Hill Publications, 2017.
2. W. F. Stoecker, *Refrigeration & Air conditioning*, 2nd ed. McGraw-Hill, 1987.
3. C. P. Arora, *Refrigeration & Air conditioning*, 2nd ed. McGraw-Hill, 2000.
5. J. P. Holman and S. Bhattacharya, *Heat Transfer*, 10th ed. McGraw Hill Education, 2002.
6. J.R. Howard, *Fluidized Bed Technology, Principles and Applications*, First Edition, CRC Press, 1989
7. A.P.E. Thummann: Fundamentals of Energy Engineering, Prentice Hall, 1984
8. Prabir Basu, Combustion and Gasification in Fluidized Beds, First Edition, CRC Press, 2006

ME6493D SEMINAR / MINI PROJECT

Pre-requisite: Nil

L	T	P	C
0	0	2	1

Total hours: 26

Students are free to select either Seminar or Mini Project.

Course Outcomes for ME6493D Seminar:

CO1: Demonstrate the ability to present a seminar in their area of interest and relate class room teaching with contemporary topics in research and practice.
CO2: Illustrate the ideas through an audience-centered presentation involving visual aids, peer feedback, and discussion prompts generated by audience.
CO3: Demonstrate effective oral/writing skills and processes by employing the rhetoric techniques of academic writing, including invention, research, critical analysis, evaluation and revision.
CO4: Construct a report by effectively documenting appropriate sources in accordance with the formatting style and utilizing the conventions of standard written English.

SEMINAR

Each student shall prepare a seminar paper on any topic of interest related to the core/elective courses undergone in the first semester of the M. Tech. programme. He/she shall get the paper approved by the Programme Coordinator/Faculty Members in the concerned area of specialization and shall present it in the class in the presence of the Faculty in-charge of seminar class. Every student shall participate in the seminar. Grade will be awarded on the basis of the student's paper, presentation and his/her participation in the seminar.

Course Outcomes for ME6493D Mini Project:

CO1: Select a research problem pertaining to the area of specialization of the M. Tech. programme.
CO2: Choose an appropriate research methodology for solving the problem identified.
CO3: Apply the methods/tools learned to solve the problem.
CO4: Construct a report by employing the rhetoric techniques of academic writing, including invention, research, critical analysis, evaluation and revision

MINI PROJECT

Students can select a research problem pertaining to the area of specialization of the M. Tech. programme by consulting a faculty in the department. The student has to identify an appropriate methodology and solve the problem. The student shall submit a report. The mini project will be evaluated by the faculty in-charge of the mini project.

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ME7494D PROJECT WORK (Phase - I)

L	T	P	C
0	0	0	12

Course Outcomes:

CO1: Choose an area of research, summarize research papers and select a research problem.
CO2: Find an appropriate research methodology for the problem chosen.
CO3: Outline the methods/tools to solve the problem.
CO4: Formulate an appropriate model for solving the problem.

Students are encouraged to identify the area of the project work and conduct the literature review during the second semester itself. The project work starts in the third semester. The topic shall be research and development oriented. The project work can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project work in an industry or in other organizations have to fulfill the requirements as specified in the "Ordinances and Regulations for M. Tech." The student is expected to complete the research problem definition, formulation and preliminary work (pilot study) in the third semester. There shall be evaluations of the project work during and at the end of the third semester by a committee constituted by the department.

ME7495D PROJECT WORK (Phase - II)

L	T	P	C
0	0	0	13

Course Outcomes:

CO1: Develop algorithms/solution procedures to solve the problem.
CO2: Analyze and interpret the results using tables and figures for visualization.
CO3: Compile the problem, solution method and the findings of the project work.
CO4: Develop an extensive and independently written thesis using relevant scientific theories/methods and defend the thesis.

The project work started in the third semester will be extended to the end of the fourth semester. There shall be evaluations of the project work by a committee constituted by the department during the fourth semester. The student shall submit the thesis based on the recommendation of the departmental evaluation committee. There shall be viva-voce examination conducted by an evaluation committee with an external examiner.

ME6421 DIRECT ENERGY CONVERSION SYSTEMS*

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Impart knowledge of the underlying principles of direct energy conversion and the technological options for its utilization in various end use applications.
CO2: Apply the principles of thermodynamics and heat transfer for the performance assessment of different direct energy conversion systems.
CO3: Design energy conversion systems based on the principles of direct energyconversion incorporating futuristic technologies like MHD generators and fuel cells.

Module 1: (13 hours)

Basic science of energy conversion - Orderly and disorderly energy - Reversible and irreversible engines - Analysis of basically reversible engines - Duality of matter - Thermoelectric Vs Photoelectric phenomena - Basic thermoelectric engine - Thermoelectric materials and applications – Fuel cells - Definition, general description, types, design and construction - Thermodynamics of ideal fuel cells - Practical considerations - Present status.

Module 2: (13 hours)

Future energy technologies - Hydrogen energy - Nuclear fusion - Thermionic emission - Richardson's equation - Analysis of high vacuum thermionic converter - Gaseous converters - Introduction to MHD generators - Seeding and ionization in MHD generators - Analysis of MHD engines and MHD equations - Conversion efficiency and electrical losses in MHD power generation systems.

Module 3: (13 hours)

Fundamentals of solar photovoltaic cells - Production of solar cells –Thin film solar cell technologies - Design concept of PV cell systems - Solar cells connected in series and parallel - Voltage regulation and energy storage - Centralized and decentralized PV System design and applications–Concentrator PV cells and systems - Maintenance of PV systems - Current developments.

References:

1. S.S.L. Chang: *Energy Conversion*, Prentice Hall, 1963
2. G.W. Sutton: *Direct Energy Conversion*, McGraw Hill, 1966
3. S.L. Soo: *Direct Energy Conversion*, Prentice Hall, 1968
4. S.W. Angrist: *Direct Endergy Conversion*, 4e, Allwyn&Bycon, 1982
5. D. Merick and R. Marshall: Energy, *Present and Future Options*, Vol I & II, John Wiley, 1981
6. B. Sorenson: *Renewable Energy*, Academic Press, 1989
8. B. Viswanathan and M. A.Scibioh: *Fuel Cells - Principles and Applications,* Universities Press, 2006
9. G. Boyle: *Renewable Energy- Power for Sustainable Future*, 2e, Oxford University Press, 2004

PS: This subject is to be handled by 50:50 sharing basis between MED & EED

ME6422D ENERGY AND ENVIRONMENT

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1:Classify components of environment.
CO2: Analyse the biogeochemical cycles
CO3: Assess different techniques for the control and management of pollution of air and water
CO4: Explain environmental impact assessment, regulatory steps in environmental sector

Module 1: (12 hours)

Energy Overview: Basics of energy - Types of energy and its utilization - Energy characteristics – Energy Measures- global energy scenario - India energy scenario- Fundamentals of environment - Water cycle - Oxygen cycle - Carbon cycle -Nitrogen cycle - Phosphorous cycle – Rock cycle - Bio-diversity - Environmental aspects of energy utilization - Public health issues related to environmental Pollution.

Module 2: (13 hours)

Air Pollution: Classification of air pollutants, sources of emission and air quality standards - Physical and chemical characteristics - Meteorological aspects of air pollutant dispersion - Temperature lapse rate and stability - Factors influencing dispersal of air pollutant - Air pollution dispersion models - Air pollution sampling and measurement - types - Ambient air sampling - Gaseous air pollutants - Particulate air pollutants - Analysis of air pollutants

Module 3: (14 hours)

Air Pollution Control methods, Types of controls – Particulate emission control - Gaseous emission control - Water Pollution Control methods: Sources and classification of water pollutants - Waste water sampling and analysis - Basic process of waste water treatment - Primary treatment - Secondary treatment - Advanced treatment Methods of feed water treatment. Environmental impact assessment: Air quality and water quality standards – Pollution prevention and control acts - Principles and methodology of Environmental impact assessment, Air and water quality impacts by project type.

References:

1. C. S. Rao, *Environmental Pollution Control Engineering*, Wiley Eastern, 1992. (*In IEEE format)*
2. Y. Anjaneyulu, *Air Pollution and Control Technologies*, Allied Publishers, 2002.
3. J. Rau and D.C. Wooten, *Environmental Impact analysis Handbook*, McGraw Hill, 1980.
4. D.H.T. Liu, *Environmental Engineers Handbook*, Lewis, 1997.

ME6423D INTEGRATED ENERGY SYSTEMS

Pre-requisites: ME6402D

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Evaluate different options of hybrid systems for a given location/application
CO2: Model and simulate the hybrid system operation
CO3: Evaluate the performance of the integrated/hybrid system
CO4: Evaluate the economic feasibility of hybrid systems

Module 1: (13 hours)

Introduction to hybrid and integrated energy systems; various options of integration, system architecture; energy storage opportunities in hybrid energy systems; assessing the consumer load demand, renewable energy resource assessment; feasibility analysis; environmental factors and regulatory requirements.

Module 2: (13 hours)

Modeling of integrated energy systems; load matching and scheduling; system operation, choice of generators, selection of diesel generator set and renewable energy based generators, dump or auxiliary heat loads, storage selection; system control, electrical safety; operational issues associated with integrated energy systems; installation and monitoring; performance analysis.

Module 3: (13 hours)

Cost parameters, indirect financial considerations of total environmental and social cost, direct financial considerations, economic appraisal methodology; recent developments, integration of biomass based systems, wind-hydropower systems, systems capable of meeting electrical and thermal loads, building integration; case studies.

References:

1. R. Hunter and G. Elliot, *Wind Diesel Systems: A Guide to the Technology and its Implementation, Cambridge University Press*, 1994.
2. J. K. Kaldellis, Stand-alone and Hybrid Wind Energy Systems Technology, Energy Storage and Applications, Woodhead Publishing Limited, 2010.
3. W. R. Murthy and G. McKay, *Energy Management*, Butherworth Heinemann, 2001.
4. S. S. Rao, *Textbook on Engineering Optimization – Theory and Practice*, 3rd ed. J. Wiley, 1996.

ME6424D ENERGY POLICIES FOR SUSTAINABLE DEVELOPMENT

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Knowledge in energy policies, their need and significance, and the implications in energy utilization.
CO2: Analyze diverse scenarios linking energy utilization and environmental issues with due consideration of the prevailing energy policies.
CO3: Apply mathematical modeling techniques for energy planning and energy policy simulation.

Module 1: (13 hours)

Energy policies - Supply focus approach and its limitations - Energy paradigms - DEFENDUS approach - End use orientation - Energy policies and development - Case studies on the effect of Central and State policies on the consumption and wastage of energy - Critical analysis - Need for renewable energy policies in India - Energy and environment - Green house effect - Global warming - Global scenario - Indian environmental degradation - Environmental laws.

Module 2: (14 hours)

Water (prevention & control of pollution) act 1974 - The environmental protection act 1986 - Effluent standards and ambient air quality standards - Latest development in climate change policies & CDM - Energy conservation schemes - Statutory requirements of energy audit - Economic aspects of energy audit - Capital investments in energy saving equipment - Tax rebates - Advantages of 100% depreciation – India's plan for a domestic energy cap and trade scheme.

Module 3: (12 hours)

Social cost benefit analysis - Computation of IRR and ERR - Advance models in energy planning - Dynamic programming models in integrated energy planning - Energy planning case studies - Development of energy management systems - Decision support systems for energy planning and energy policy simulation.

References:

1. J. Goldemberg, T.B. Johansson, A.K.N. Reddy and R.H. Williams: *Energy for a Sustainable World*, Wiley Eastern, 1990
2. A.K.N. Reddy and A.S. Bhalla: *The Technological Transformation of Rural Inda*, UN Publications, 1997
3. A.K.N. Reddy, R.H. Williams and J.B. Johanson: *Energy After Rio-Prospects and Challenges*, UN Publications, 1997
4. P. Meier and M. Munasinghe: *Energy Policy Analysis & Modeling,* Cambridge University Press, 1993
5. R.S. Pindyck and D.L. Rubinfeld*: Economic Models and Energy Forecasts*, 4e, McGraw Hill, 1998

ME6425D OPTIMAL DESIGN OF HEAT EXCHANGERS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1:Outline the fundamentals of optimal heat exchanger design
CO2: Identify the methods of sizing and design of heat exchangers
CO3: Examine the fundamental equations and solution methods for heat exchangers
CO4: Assess the practical considerations and applications of cryogenic and multi stream heat exchangers

Module 1 (12 hours)

Heat exchanger classification and design fundamentals - LMTD-NTU rating and sizing problems - Theta methods - Dimensionless groups - Steady-state temperature profiles - Optimization criteria - Core pressure loss.

Module 2 (16 hours)

Direct sizing of heat exchangers - Plate fin exchangers - Exchanger lay out– Surface geometries - Distribution headers - Multi-stream design - Helical-tube exchangers - Design frame work - Basic and simplified geometries - Fine tuning and design for curved tubes - Bayonet tube exchangers - Isothermal and non-isothermal shell side conditions - Explicit, complete and non-explicit solutions.

Transients in heat exchangers - Fundamental equations - Solution methods – Analytical considerations - Method of characteristics - Direct solution by finite differences - Engineering applications

Module 3 (11 hours)

Single-blow testing and regenerators - Theory and physical assumptions - Choice of test method - Practical considerations - Cryogenic heat exchangers - Direct sizing and stepwise rating of multi-stream heat exchangers - Commercial applications.

References

1. E.M. Smith: *Thermal Design of Heat Exchangers*, John Wiley, 1999
2. A.P. Fraas: *Heat Exchanger Design*, 2e, J. Wiley, 1989
3. W.M. Rohsenow and J.P. Harnett: *Handbook of Heat Exchanger Application*, McGraw Hill, 1985
4. D.Q. Kern: *Process Heat Transfer*, McGraw Hill, 1950

ME6426D FLUIDIZED BED SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1. Knowledge in fluid dynamics and heat transfer phenomena occurring in a fluidized bed.
CO2. Carry out the design of fluidized bed system for combustion and gasification.
CO3. Capability to develop mathematical models applicable to of fluidization process involving multiphase conditions, combustion and gasification.
CO4. Awareness of application of fluidized bed systems in furnaces and boilers, fluidized bed steam generator for liquid metal fast breeder reactors and pressurized fluidized bed combustion boilers.

Module 1 (12 hours)

Introduction to fluidized bed technology - Regimes of fluidized behavior - Heat transfer in fluidized bed - Residence time distribution and size distribution in fluidized bed – Heat transfer to immersed surfaces in fluidized and packed beds – Application of Fluidized bed technology in heat exchangers, furnaces and boilers.

Module 2 (15 hours)

Theory of fluidized bed combustion (FBC) - System design for combustion and gasification - Fluidized bed combustion systems for power plants - Air distribution design - Combustion efficiency - Start up and shut down - Combustion of coal in fluidized beds – De sulfurization of coal in fluidized bed - Use of wood and agricultural waste for fluidized bed combustion – Theory of pressurized fluidized bed and pressurized adiabatic fluidized bed.

Module 3 (12 hours)

Mathematical modeling of fluidization process - Multiphase models - Fluidized bed gasification systems - Production of gaseous fuels form coal in fast fluidized beds -Chemically active fluidized bed gasifier - Conversion of gas in bubbling beds -Entrainment and elutriation.

References

1. J.R. Howard,*Fluidized Bed Technology, Principles and Applications*, First Edition, CRC Press, 1989
2. D. Kunii and O. Levenspiel,*Fluidization Engineering*, Second Edition, Butterworth-Heinemann, 2013
3. J.F. Davidson and D. Harrison: *Fluidization*, Academic Press, 1971
4. DimitriGidaspow, *Multiphase Flow and Fluidization*, Academic Press, 2012
5. L.G. Gibilaro, *Fluidization Dynamics*, Butterworth-Heinemann, 2001

ME6427D HEAT PUMP TECHNOLOGY

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1. Apply thermodynamics for heat pump systems for specific applications.
CO2. Carry out the design of vapour compression and absorption heat pump systems.
CO3. Capability to carry out the performance assessment of different types of heat pumps.
CO4. Knowledge of advances in heat pump technology including advanced cycles for vapor absorption heat pumps, Peltier-effect heat pumps, magnetic heat pumps etc.

Module 2 (12hours)

Heat pump theory: Heat pump-refrigeration cycles–Vapour compression and vapour absorption heat pump systems - Heat pump circuits –Common sources used for heat pumps - Comparison of water-source and air-source heat pumps – Heat pump performance – Exergy analysis of heat pump.

Module 2 (15 hours)

Design of heat pump systems:components of heat pumps–compressor and prime mover types and performance - heat transfer components –condensers and evaporators - expansion and metering devices - reversing valves, filters, drier, receiver and accumulator - auxiliary heating elements - selection of working fluid - refrigerant piping and pipe insulation - various control and wiring circuits - Part-load performance of components.

Module 3 (12 hours)

Heat pump performance evaluation - Seasonal performance factor - Comparison of solar assisted heat pumps - Applications of heat pump systems - Reliability and maintenance of heat pumps.
Advances in heat pumps - Improvements and innovations - Advanced cycles for vapor absorption heat pumps –Hybrid heat pumps - Peltier-effect heat pumps - Magnetic heat pumps – Heat transformers - Metal hydride heat pumps - Energy basis comparison of convention and advanced heating and cooling systems.

References

1. Billy C. Langley, *Heat Pump Technology,*Third Edition, Pearson, 2001
2. Eugene Silberstein**,** *Heat Pumps***,** Second Edition**,** Delmar Cengage Learning, 2015
3. Lee Miles, *Heat Pumps: Theory and Service*, First Edition, Delmar Cengage Learning, 1993
4. Billy C. Langley, *Heat Pump Technology: Systems Design, Installation*, *and Troubleshooting*, Second Edition, Pearson College Div, 1989
5. Randy F. Petit Sr., Turner L. Collins, *Heat Pumps: Operation, Installation, Service*, Esco Press, 2011

ME6428D DESIGN OF SOLAR THERMAL SYSTEMS

Pre-requisites:ME6402D

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyze the solar thermal options based on the specified application
CO2: Estimate the process loads for the solar thermal application
CO3: Design the solar thermal system using characteristic equations
CO4: Analyze the techno-economics and arrive at optimum system design

Module 1: (13 hours)

Solar radiation and solar geometry; solar collector technologies: flat plate, evacuated tube and concentrators; options for thermal storage; typical solar thermal applications, modeling of thermal equipment and system simulation; elements of system optimization.

Module 2: (13 hours)

Flat plate collectors:collector characterization and design parameters; energy storage in solar process systems; solar process loads; system thermal calculations; estimation of building heating/cooling loads, passive, active and hybrid systems for building applications; design of active systems: *f* chart and utilizability methods.

Module 3: (13 hours)

Concentrator systems: optics for solar collectors, non tracking and tracking concentrators, optical analysis and optimization of parabolic reflectors, concentrating solar power technology: Linear Fresnel Reflector receivers and thermal performance, design and analysis of parabolic-trough, central tower and parabolic dish systems, heliostat design issues, case studies on system design and optimization.

References:

1. J. A. Duffie and W. A. Beckman, *Solar Engineering of Thermal Processes*, 4th ed. Wiley, 2013.
2. A. Rabl, Active *Solar Collectors and Their Applications*, Oxford University Press, 1985.
3. D. Y. Goswami, F. Kreith, and J. F. Kreider, Principles of Solar Engineering, 2nd ed. CRC Press, 2000.
4. K. Lovegrove and W. Stein, Concentrating Solar Power Technology, Woodhead Publishing Ltd, 2012.

ME6429D ENERGY EFFICIENT BUILDINGS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Evaluate comfort conditions for a given zone
CO2: Selection of energy efficient technologies for the buildings.
CO3: Modelling and simulation of building performance
CO4: Impart knowledge on recent advancements in this field

Module 1: (11 hours)
Thermal comfort, Different climate zones, Thermal comfort based on climatic zones, Evaluation of thermal comfort standards, Principles of Energy efficient building, Design guidelines, Site planning, Solar architecture, Day lighting.

Module 2: (17 hours)

Energy demand for buildings: Estimation, Effect of thermal comfort and outdoor climatic conditions,Passive technologiesfor cooling and heating: Building envelope, Thermal insulation materials, Phase change materials, Radiation shields, Ventilation techniques, and Moisture control.Active technologies: Heating Ventilation and Air Conditioning (HVAC). Recent technologies: Solar based systems, Building integrated systems. Strategies to reduce energy demand, Control systems for energy efficient buildings.

Module 3: (11 hours)

Building performance modelling and simulation tools: Software packages and coding, Energy efficient building standards: National and International Codes, Case studies: Historic and modern buildings, Residential and commercial buildings, Schools and hospitals etc.

References:

1. J. A. Clarke, *Energy Simulation in Building Design* (2e) Butterworth 2001.
2. J. K. Nayak and J. A. Prajapati,*Handbook on Energy Conscious Buildings*, Solar Energy control MNES, 2006.
3. *Energy conservation Building Codes* 2006; Bereau of Energy Efficiency.
4. J. R. Williams, *Passive Solar Heating*, Ann Arbar Science, 1983.
5. R. W. Jones, J. D. Balcomb, C. E. Kosiewiez, G. S. Lazarus, R. D. McFarland and W. O. Wray, *Passive Solar Design Handbook*, Vol. 3, Report of U. S. Department of Energy (DOE/CS-0127/3), 1982.
6. M. S. Sodha, N. K,.Bansal, P. K. Bansal, A. Kumar and M. A. S. Malik. *Solar Passive Building*, *Science and Design*, Pergamon Press, 1986.
7. J. L. Threlkeld, *Thermal Environmental Engineering*, Prentice Hall, 1970

ME6430D BIOFUELS: PRODUCTION AND APPLICATIONS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1. Knowledge on different bio-fuel production methods.
CO2. Analyse different biofuel conversion processes and predict the end products.
CO3. Select suitable bio-fuel for a particular application considering economics and minimum environmental impact.

Module-1 (13 hours)

Biofuel and bioenergy production: Energy perspective - Biomass prospects – Organic compounds – Chemistry of biomass materials – bio-renewable resources – herbaceous crops – woody crops – algae – thermodynamics of bioenergy.

Module-2(13 hours)

Conversion of biomass into heat, power and fuel – direct combustion – gasification – anaerobic digestion – Biomass into chemicals and fuels: sugars, biodiesel, thermochemical conversion, Fischer Tropsch fuels.

Module-3 (13 hours)

Applications of biofuels in automobiles, power plants, and aviation - Environmental aspect of the biofuels - Land use – Pollution - Climate change – Economics and life-cycle analysis of biofuel - Value adding of biofuel residues

References

1. David M. Mousdale, *Introduction to Biofuels*, CRC Press, 2017
2. M.R. Riazi, David Chiaramonti (Editors), *Biofuels Production and Processing Technology*, First Edition, CRC Press, 2017
3. John Love, John A. Bryant (Editors), *Biofuels and Bioenergy*, First Edition, Wiley-Blackwell, 2017
4. Pogaku Ravindra, RosalamHj. Sarbatly (Editors), *Advances in Biofuels*, Springer, 2013
5. Ram Sarup Singh, Ashok Pandey, Edgard Gnansounou (Editors), *Biofuels: Production and Future Perspectives*, First Edition, CRC Press, 2016
6. Ashok Pandey (Editor), *Handbook of Plant-Based Biofuels,* CRC Press, 2008
7. A.S. Ramadhas, *Alternative Fuels for Transportation*, CRC Press, 2010.

ME6431D MICRO-CHANNEL FLOW AND MIXING ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1:Analyze micro-fluidic systems and related applications
CO2: Knowledge in mixing in micro-systems and turbulence mixing analysis
CO3: Carry out micro-fabrication and measurements

Module 1: (13 hours)

Physics at the micrometric scale – Miniaturization of systems – Hydrodynamics of micro-fluidic systems – Interface phenomena in micro-fluidics – Diphasic flows and emulsions in Microsystems - Electro hydrodynamics in microsystems – Electro-osmosis and electrophoresis in micro-channels – Effect of surface heterogeneity on electro-kinetic flow.

Module 2: (13 hours)

Experimental studies of electro-osmotic flow – Electrophoretic motion of particles in micro-channels - Diffusion, mixing and separation in Micro-systems – Advection–diffusion equation – Analysis of dispersion phenomena – Introduction to turbulence and chaos – Chaotic mixing and chaotic advection – Cascade models for turbulence and mixing analysis – Examples for mixing in Micro-systems.

Module 3: (13 hours)

Special topics in micro-fluidics – Thermalization of heat source in Micro-systems - Evaporation and boiling in micro-channels – Micro-exchangers for electronic components – Micro-fabrication – Photolithography – Fabrication of glass and plastic MEMS – Micro-fluidic structures – Micro-fabricated valves and pumps – Micro-fluidics for biomedical applications.

References:

1. P. Tabeling: Introduction to Microfluidics, Oxford University Press, 2005.
2. G. E. Karniadakis, and A. B. N. Aluru: Micro flows and Nanoflows– Fundamentals and Simulation, Springer 2005.
3. D. L. Electrokinetics in Microfluidics, Elsevier Academic Press, 2004.
4. D. R. Crow: Principles and Applications of Electrochemistry, 4th Edition, Blackie Academic & Professional, 1994.
5. H. Chate, E. Villermanx and J. M. Chomaz (Ed.): Mixing – Chaos and Turbulence, Kluwer Academic / Plenum Publishers, 1999.
6. J. Malmivuo and R. Plonsey: Bioelectromagnetism, Oxford University Press, 1995.

ME6432D ADVANCED AIR BREATHING PROPULSION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Adoption of compressible flow parameters in designing the propulsion systems;
CO2: Thermal design of air-breathing propulsion engines;
CO3: Configure the different components of air-breathing engines;
CO4: Utility of shock trains in design of supersonic air-breathing engines;

Module 1: (11 hours)

Review of Fundamentals: Equations of state; conservation of mass; conservation of energy; steady flow momentum equation; steady flow entropy equation; compressible flow properties; chemical reactions for propulsion applications. Introduction to Propulsion; operational envelopes and standard atmosphere; air-breathing engines; rocket engines; aircraft performance.Principles of air breathing propulsion systems, performance parameters.

Module 2: (14 hours)

Classification of engines: ramjet engine; turbojet engine; turbofan; turboprop; turboshaft; thermodynamics cycle and performance analysis; Specific thrust; specific fuel consumption; specific impulse; thermal and propulsion efficiency. Components - diffuser; compressor; fan; turbine; propeller; combustor; after burner; nozzles. Component losses.Axial flow compressors and turbines; centrifugal compressors; velocity triangles; single-stage energy analysis.

Module 3: (14 hours)

Primary combustors and after-burners; flame stability; ignition; engine starting; adiabatic flame temperature; fuel-air mixing; SCRAM jet engines; combined Rayleigh and Fanno flow analysis; supersonic inlets and combustors; scram jet with shock-free isolators; scram jet with oblique shock trains, Hypersonic air-breathing propulsion. CFD applications; experimental and testing facilities- the shock tunnel.

References:

1. Ronald D Flack, Fundamentals of Jet Propulsion with Applications, Cambridge University Press, New York, 2005
2. Jack D. Mattingly, Elements of Gas Turbines Propulsion, Tata McGraw Hill companies, New York, 1996.
3. Philip Hill and Carl Peterson, Mechanics and Thermodynamics of Propulsion, Second edition, Pearson Education Inc. Prentice Hall, 1992.
4. William H. Heiser and David. D. Pratt, Hypersonic Airbreathing propulsion, AIAA Education Series, Washington, DC 1994.
5. E T Curran and SNB Murthy, Scramjet Propulsion, Progress in Astronautics and Aeronautics, Volume 189, AIAA, Virginia, 2000.

ME6433D CRYOGENIC ROCKET PROPULSION SYSTEMS

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1. Knowledge in liquid propellant rocket engine system and components, analyze the performance of liquid propellant rocket engines.
CO2. Capability to perform heat transfer and fluid flow analysis ofthrust chambers and other combustion devices in propulsion systems
CO3. Analyse typical engine cycles and new trends, gas pressurized propellant feed system, carry out preliminary design of the liquid engines.
CO4. Analyse and apply principles of rocket engine control and associated condition monitoring systems

Module 1 (10 hours)

Introduction to liquid propellant rocket engines: Basis elements of liquid propellant rocket engines, generation of thrust, gas flow processes in the combustion chamber and nozzle, performance parameters of a liquid propellant rocket engines, liquid propellants- Earth storable and cryogenic, engine requirements and preliminary analysis- major rocket engine design parameters, mission requirements, Engine design philosophy, Preliminary design, sample calculations

Module 2 (9 hours)

Thrust chambers and other combustion devices: Basic thrust chamber elements, thrust chamber performance parameters, specific impulse, characteristic velocity, thrust coefficient, performance calculations, thrust chamber configuration layout, heat transfer and fluid flow, injectors, ignition devices, combustion instability

Module 3 (10 hours)

Typical engine cycles and new trends, gas pressurized propellant feed system: Determination of pressurant requirements, turbo pump propellant feed system, elements of turbo pump fed systems, propellant pumps, turbines, turbine power sources, turbo pump drive arrangements, turbo pump design parameters, turbo pump system performance and design, design of centrifugal pumps, axial flow pumps, turbine design, turbo pump-roto dynamics and mechanical elements, propellant tanks, cryogenic propellant tank design, insulation requirements for cryogenic propellant tanks, basic insulation types, selection of tank insulation designs, insulation for common bulk heads

Module 4 (10 hours)

Rocket engine control and condition monitoring systems**:** Basic liquid propellant engine control systems, engine thrust level control, propellant mixture ratio and propellant utilization control, thrust vector control, CCM concepts and preliminary design development, control methods, control law development, design of fluid flow control devices, engine systems integration, space engines and considerations, space applications, reaction control engine requirements, altitude control weight, reliability and material considerations.

References

1. HILL, PHILIP G, PETERSON, CARL R, Mechanics and thermodynamics of propulsion,
2. ZUCROW, M.J., Air craft and missile propulsion,
3. CARTON, D.S., Rocket propulsion technology,
4. JAUMOTTE, A.L., Combustion and propulsion,
5. BONNEY, E. Arthur, Aerodynamics propulsion structures and design practical,

6. FLACK, RONALD D., Fundamentals of jet propulsion with applications,
7. YAHYA, S.M., Fundamentals of compressible flow with aircraft and rocket propulsion,
8. T LANCASTER O.E., Jet propulsion engines,
9. KUENTZ, CRAIG, Understanding rockets and their propulsion,
10. NASA-SP-125
11. NASA-SP-273

ME6434D ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Analyse the component of environment and natural cycles
CO2: Assess different techniques for the control and management of pollution of air and water
CO3: Inspect different techniques for control of noise pollution, oil pollution
CO4: Elaborate Environment Impact assessment methods

Module 1: (11 hours)

Fundamentals of environment-Green house gases and effect –Global warming–Ozone Depletion Acid rain, Natural Cycles- Water cycle, Oxygen cycle , Carbon cycle, Nitrogen cycle Phosphorous cycle, Sulphur cycle - Bio-diversity- Environmental legislations.

Module 2: (13 hours)

Classification of air pollutants, sources of emission and air quality standards - Meteorological aspects of air pollutant dispersion - Temperature lapse rate and stability - Factors influencing dispersal of air pollutant - Air pollution dispersion models - Air pollution sampling and measurement - Control Methods and Equipments - Issues in Air Pollution control

Module 3: (15 hours)

Water resources -Sources and classification of water pollutants - Waste water analysis - Basic process of water treatment - Primary treatment -Secondary treatment - Advanced treatment. Disposal of Sludge - Monitoring compliance with Standards. Noise Pollution and its impact - Oil Pollution - Pesticides - Instrumentation for EIA test - Instrumentation related with parameter of pollutants – Environment Impact assessment for various projects – Case studies

References:

1. C. S. Rao, *Environmental Pollution Control Engineering*, Wiley Eastern, 1992.
2. Y. Anjaneyulu, *Air Pollution and Control Technologies*, Allied Publishers, 2002.
3. G. Masters, *Introduction to Environmental Engineering and Science*, Prentice Hall of India Pvt Ltd, New Delhi, 2003.
4. H.S. Peavy, D.R. Rowe, G. Tchobanoglous, *Environmental Engineering* -McGraw- Hill Book Company, New York, 1985.
5. H. Ludwig, W. Evans, *Manual of Environmental Technology in Developing Countries*, International Book Company, Absecon Highlands, N.J,1991.
6. Arcadio P Sincero and G. A. Sincero, *Environmental Engineering – A Design Approach*, Prentice Hall of India Pvt Ltd, New Delhi, 2002.
7. J. Rau and D.C. Wooten, *Environmental Impact Analysis Handbook*, McGraw Hill, 1980. *(In IEEE format)*

ME6434D HYDROGEN - PRODUCTION, STORAGE AND TRANSPORTATION

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1: Knowledge in different technological options in hydrogen production, storage and transportation.
CO2: Analyze and carry out the underlying principles of hydrogen production, storage and transportation for worldwide energy problems.
CO3:Knowledge of hydrogen storage and transportation options for its utilization in various fields of applications.

Module 1 (11 Hours)
Introduction: Need for Hydrogen Energy: Global energy picture, World wide Energy Problems, Security of Energy Supplies. Present and Projected uses for Hydrogen, Prospects, Prognosis and future for Hydrogen energy. Prospects for a Cleaner Planet: Climate Change, Challenges.
Production of Molecular Hydrogen: From fossil fuels, synthetic fuels and nature's production. Understanding Processes: Thermo-chemical, Photo-chemical, Bio-chemical, Electro-chemical. Gas separation, Photosynthesis, Thermal decomposition. Electrolysis of water: High pressure electrolysis, Low pressure electrolysis, High-temperature electrolysis, Electrolyzers.
Using Solar energy: Photochemical, Photo-catalytic, the water oxidation in nature, Artificial photosynthesis, Hydrogenases and biomimics. Solar cracking: photo-electrochemical. Water Splitting with Solar Energy, Photovoltaic Cells, Solar Thermal Process, Photo-electrochemical Cells, Dye-sensitized Solar Cells, Direct Hydrogen Production Tandem Cells, Photo-biochemical Cells.

Module 2 (14 Hours)
Thermo-Chemical Hydrogen Production Process and Direct Chemical Path: Thermo-chemical production of hydrogen using chemical energy from coal or natural gas, direct chemical path. Hydrogen from fossil fuels, coaland organic compounds.Cracking, Reforming of Natural gas.Steam Reforming of Methane, Solar thermal reforming partial oxidation of hydrocarbons, Auto-thermal reforming, Sorbent-enhanced reforming, Plasma reforming. From Ethanol & Methanol, Dry biomass, Wet biomass, Thermo-chemical hydrogen production, Sulfur Iodine cycle, Westinghouse cycle, Sulfur Ammonia cycle, Metal oxide cycles. Thermal decomposition, Thermo-chemical cycles for water splitting, Iron oxide cycle, cerium (IV) oxide-cerium (III) oxide cycle, Zinc zinc-oxide cycle, Sulfur-iodine cycle, Copper-chlorine cycle and Hybrid sulfur cycle without using heat or electricity.
Gas Separation: Gas Separation Processes, Membrane types and membrane development for gas separation, Membrane reactors, Gasification technology, Entrained-flow gasifier, Moving-bed gasifier, Fluidized-bed gasifier.

Module 3 (14 Hours)
Storage, Transportation and Distribution: Basic hydrogen storage technologies, Liquid hydrogen storage, Liquefaction cycles, Slush hydrogen, Hydrogen purification, Liquefied form in Dewars, Dewars for stationary and transport applications. Hydrogen storage in solids: Metal hydrides, Metallic alloy hydrides, Carbon nano-tubes.
Strategic Considerations, Distribution and Bulk storage of gaseous, Dewars for transport applications gas cylinders, Pipelines, Large-scale storage, Metal hydrides, Chemical and related storage, Simple hydrogen-bearing chemicals, Complex chemical hydrides, Nano-structured materials, Hydrogen storage in road vehicles, Industrial scale pressurized hydrogen storage.

References

1. J. Bard and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications, 2nd Edition, Wiley 2000
2. Faghri and Y. Zhang, Transport Phenomena in Multiphase Systems, Elsevier 2006
3. Green Reaction Media in Organic Synthesis by Mikami Koichi Wiley-Blackwell 2005
4. Koichi Tanaka Solvent-free Organic Synthesis Green chemistry Wiley-VCH; 2003

5. Maartje F. Kemmere and Thierry Meyer Supercritical Carbon Dioxide: in Polymer Reaction Engineering Green Chemistry Wiley VCH 2005.
6. AlvisePerosa, FulvioZecchini, and PietroTundo Methods and Reagents for Green Chemistry: An Introduction Wiley Inter science 2007
7. The Solar Hydrogen Civilization, Roy McAlister, www.knowledgepublications.com
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ME6435D HYDROGEN ENERGY CONVERSION TECHNOLOGY

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Course Outcomes:

CO1: Knowledge in different technological options in using hydrogen as fuel in heat engines.
CO2: Analyze and carry out the underlying principles of hydrogen energy conversion technology for worldwide energy problems.
CO3:Knowledge of hydrogen and fuel cells as technological options in transport sector.

Module 1 (10 Hrs)
Introduction: Present and projected uses for hydrogen, Prospects, Prognosis and future. Hydrogen as tomorrow's energy: Energy, environment and economy of futuristic hydrogen, Opportunities and challenges. Prospects for a cleaner planet.Hydrogen road map-the next hundred years. Hydrogen energy chain: Transport, Stationary power, Portable power and other applications. Environmental concerns and cost, Examples and pilot programs, Hydrogen prize.

Module 2 (14 Hrs)
Hydrogen as a fuel in heat engines: Stationary and powering vehicles in road transport and aviation industry, Hydrogen energy, Hydrogen as a fuel, Liquid and Gaseous Fuels. Physico-chemical characteristics. Efficiency calculations and fuel consumption, Internal combustion engines and aircraft. Hydrogen-fuelled Transportation: Conventional vehicles, Fuel supply system, emission and control. Hydrogen combustion characteristics, instability, detonation and flashback control techniques. Safety aspects and system development, NOx emission control. Hydrogen internal combustion engine vehicle, Efficiency as an automotive fuel. Air-breathing reciprocating engines and gas turbines fueled with hydrogen, Disc and Warp Drive hydrogen combustionEngines.
Other applications: In large & small stationary power generation, Portable power, Air-breathing reciprocating engines and gas turbines fueled with hydrogen. Basic principles for the design and optimisation of hydrogen-based autonomous power systems, Barriers and benefits of hydrogen-based autonomous power systems. Environment benefits of hydrogen-based autonomous power systems. Roadmap to commercialisation of hydrogen-based autonomous power systems.

Module 2 (18 Hrs)
Fuel cell engine vehicles (FCVs): Fuel cells as alternative to internal combustion buses, Delivery vehicle, Cars and other Automobiles, Non transport applications, Submarines, Hybrid Electric Vehicles (HEVs), Conventional versus hybrid vehicles.
Traction mechanisms: Used for fuel cell operated, Comparison with pure battery operated, Combo drives: Battery & fuel cell, Battery and hydrogen cum gasoline engine, Fuel cell and Hydrogen cum Gasoline engine.
Metering, instrumentation and safety issues: EMS, **S**afety issues, Instrumentation in hydrogen usage. **L**eak detectors used in production, transport and conversion, Hydrogen sniffer leak detection solution. Problems in hydrogen usage: Hydrogen embrittlement, Hydrogenation of oils.

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ME6437D ENERGY MODELING, ECONOMICS AND PROJECT MANAGEMENT

Pre-requisites: NIL

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Capability to analyze energy policies and suggest novel ideas on policies.
CO2: Apply quantitative techniques for analyzing energy resource and demand.
CO3: Apply the concepts of economics in the energy sector.
CO4: Systematic analysis of energy projects considering economic aspects.

Module 1: (13 hours)
Energy modeling: The energy imperative and patterns of use, planning and visioning the energy future;energy analysis and life-cycle assessment; demand forecasting, econometric approach to energy demand forecasting,common energy demand analysis models; integrated national energy planning; market transformation to sustainable energy; energy policy, role of modeling in energy policy analysis.

Module 2: (13 hours)
Energy economics: scope, energy and multidimensional interactions,energy data and energy balance; economic analysis of energy investments, economics of fossil fuel supply, economics of renewable energy supply; energy markets and principles of energy pricing, energy pricing and taxation; impact of high energy prices.

Module 3: (13 hours)
Project management: financial estimates and projections, project cash flows, time value of money; feasibility analysis, project appraisal criteria, risk analysis, project planning matrix; social cost benefit analysis; network analysis for project management, time estimation, critical path determination, PERT, CPM; Implementation and monitoring, performance indices; case studies in energy sector.

References:

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ME6438D HYDROPOWER SYSTEMS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1: Assess the performance of hydropower systems through model analysis and suggest design modifications in prototype.
CO2: Design the various components of hydropower systems and supervise construction of hydro-electric power projects.
CO3: Estimate the cost of power projects considering economic factors and prepare project reports.

Module 1: (14 hours)

Principles of modeling and similitude as applied to Turbo-machines- Euler's turbine equation - Analysis of turbines-constructional features of Pelton, Francis and Kaplan turbines. Performance evaluation and governing of turbines.Development of prototype systems.Power station operation and maintenance. Load control and controlling power distribution. Reservoirs.Importance of Mini and micro-hydro power systems.

Module 2: (10 hours)

Overview of Hydropower systems.Case studies. Preliminary Investigation-Determination of Requirements- preparation of Reports and Estimates-Review of World Resources-Cost of Hydroelectric Power-Basic Economic Factors

Module 3: (15 hours)

Analysis of Hydropower projects-Project Feasibility-Load Prediction and Planned Development-Advances in Planning, Design and Construction of Hydroelectric Power Stations-Trends in Development of Generating Plant and Machinery-Plant Equipment for pumped Storage Schemes-Some aspects of Management and Operations-Updating and Refurbishing of Turbines.
Governing of Power Turbines-Functions of Turbine Governor-Condition for Governor Stability-Surge Tank Oscillation and Speed Regulative Problem of Turbine Governing in Future Problem of management-Maintenance of Civil Engineering works-Maintenance of Electrical Engineering works Computer aided Hydropower System Analysis-Design-Execution-Testing-Operation and control of Monitoring of Hydropower Services.

References:

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ME6439D WIND ENERGY TECHNOLOGY

Pre-requisites: nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1:Analyze the basic necessary components for the design of wind turbine;
CO2: Employ the concepts of aerodynamics for efficient blade design;
CO3: Design the wind turbines/farms in context with Indian wind scenario;

Module 1: (11 hours)

Introduction to wind power; wind power scenario in India; wind characteristics – extractable limits of wind power; wind power potential; gust/extreme wind speeds; wind turbulence; wind measurement and instrumentation; horizontal/vertical axis wing turbines; wind turbine topologies

Module 2: (14 hours)

Wind turbines; drag and lift in turbine blades; orientation of rotor axis; aerodynamics of horizontal axis wind turbines; simple momentum theory and power coefficient; Betz limit; rotor disc theory- angular momentum theory and maximum power; blade geometry-a simple blade design; optimal design at constant speed and variable speed operation; losses in blades; wind turbine performance curves; performance measurements.

Module 3: (14 hours)

Components of horizontal axis wind turbines-blades; pitch bearings; rotor hub; gear box; generator; nacelle; yaw drive; tower. Wind turbine loads on wind turbine components; conceptual design of horizontal axis wind turbines-blades – rating; rotational speed; number of blades; teetering; braking systems; wind turbine materials; wind turbine installations and wind farms in India; off-shore wind turbines; wind energy system economics; small wind turbines.

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2. James F. Manwell, Jon G. McGowan, Anthony L. Rogers, *Wind Energy Explained: Theory, Design and Application*, 2nd Edition, John Wiley & Sons, Ltd., 2010.
3. Vaughn Nelson, *Wind Energy: Renewable Energy and the Environment*, Second Edition, CRC Press, 2013
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ME6440D THERMODYNAMIC PROPERTY RELATIONS AND EXERGY ANALYSIS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Course Outcomes:

CO1:Analyse different thermodynamic processes based on the first law
CO2: Evaluate the properties of single phase and two phase thermodynamic systems
CO3: Exergy analysis of different thermodynamic cycles and engineering devices

Module 1: (14 hours)
Introduction to thermodynamics, review of 1st law, work and heat transfer, properties of pure substances, review of 2nd law, entropy,practical applications.
Thermodynamic property relations:Two constant and multi constant equations of state; Relevant mathematical relations; T-ds equations; Helmoltz and Gibbs functions; Maxwell's relations; Difference in heat capacities; ratio of heat capacities;Evaluation of change in internal energy, enthalpy and entropy, energy equation;specific heat relations; Joule-Thomson coefficient; Clausius-Clapeyron equation; Bridgman Tables for Thermodynamic relations; Evaluation of thermodynamic properties from an equation of state; Gas mixtures; Applications to ideal and real gases.

Module 2: (13 hours)
Definition of exergy; forms of exergy; simple examples of calculation; the destruction of exergy. Exergy balance in thermodynamic systems, Exegetic efficiency, exergy and irreversibility, Exergy analysis of thermodynamic systems, Heat exchange - Expansion Pressure let down - Mixing - Distillation - Combustion air pre-heating – Systematic design method, closed and open systems.

Module 3: (12 hours)
Applications of exergy analysis of thermodynamic operations and cycles, Air standard cycles; Carnot, Otto, Diesel, Dual and Stirling cycles, p-v and T -s diagrams, description, efficiencies and mean effective pressures. Gas turbine (Brayton) cycle; description and analysis.Performance improvement of gas turbines; Regeneration cycle – conventional, alternative, Staged heat recovery.

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