Department of Mechanical Engineering

Curriculum for M. Tech. in Energy Engineering and Management

Semester 1

Code	Title of Course	L/T	P/S	C
MA6001	Mathematical methods	3	--	3
ME6401	Advanced energy conversion systems	3	--	3
ME6402	Renewable energy technology	3	--	3
EE6001	Electrical energy systems and management	3	--	3
	Elective-I	3	--	3
	Elective-II	3	--	3
ME6491	Computational Laboratory	--	3	1
ME6492	Seminar	--	3	1
	Total	**20**		

Semester 2

Code	Title of Course	L/T	P/S	C
ME6411	Fluid flow and heat transfer in energy systems	3	--	3
ME6412	Design and analysis of energy systems	3	--	3
ME6413	Energy conservation in thermal systems	3	--	3
ME6414	Energy and Environment	3	--	3
	Elective-III	3	--	3
	Elective-IV	3	--	3
ME6493	Energy Engineering Laboratory	--	3	1
ME6494	Term Paper/Mini Project/Industrial Training	--	3	1
	Total	**20**		

Semester 3

Code	Title of Course	L/T	P/S	C
ME7495	Project work	--	--	8
	Total	**8**		

Semester 4

Code	Title of Course	L/T	P/S	C
ME7496	Project work	--	--	12
	Total	**12**		

Total Credits: 60

Note: Students have option to credit two electives in Third Semester, drawing one each from First and Second Semesters.

Students may undergo Industrial Training during the semester break.

List of Electives

Sl. No.	Code	Title	Credit
1	ME6421	Direct energy conversion systems	3
2	ME6422	Optimal design of heat exchangers	3
3	ME6423	Energy policies for sustainable development	3
4	ME6424	Fluidized bed systems	3
5	ME6425	Heat pump technology	3
6	ME6426	Micro-channel flow and mixing analysis	3
7	ME6427	Energy efficient buildings	3
8	ME6428	Integrated energy systems	3
9	ME6429	Theory of combustion	3
10	ME6430	Advanced air breathing propulsion	3
11	ME6431	Cryogenic rocket propulsion systems	3
12	ME6432	Environmental engineering and pollution control	3
13	ME6433	Emerging trends in refrigeration systems	3
14	ME6434	Hydrogen production, storage and transportation	3
15	ME6435	Hydrogen energy conversion technology	3
16	ME6436	Energy modeling, economics and project management	3
17	ME6437	Hydropower Systems	3
18	ME6438	Information technology in Energy Management	3
19	ME6439	Recent Advances in Refrigerants	3
20	ME6103	Accounting and Finance for Management	3
21	ME6212	Advanced Computational Methods in Fluid Flow and Heat Transfer	3
22	ME6214	Cryogenic Engineering	3
23	ME6221	Thermal Environmental Engineering	3
24	ME6229	Multiphase Flow	3
25	ME6230	Industrial Food Preservation	3
26	ME6232	Advanced Instrumentation Systems	3
27	ME9401	Research methodology	3

Detailed Syllabi for the M.Tech. Programme in
ENERGY ENGINEERING AND MANAGEMENT

MA6001 MATHEMATICAL METHODS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I Linear Algebra (11 Hours)

Vector spaces, Basis, Dimension, Inner product spaces, Gram-Schmidth Process, Linear Transformations, Range and Kernel, Isomorphism, Matrix of transformations and Change of Basis.

Module II Series Solutions of ODE and Sturm-Liouville (10 Hours)

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 III Partial Differential Equations (11 Hours)

First order PDEs, Linear equations, Lagrange method, Cauchy method, Charpits method, Jacobi method. Second order PDEs, Classifications, Formulation and method of solutions of Wave equation, Heat equation and Laplace equation.

Module IV Tensor Calculus (10 Hours)

Line, area and volume integrals, 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. Stephen Andrilli & David Hecker: Elementary Linear Algebra, Third Edition, Academic Press, 2003.
4. W. W. Bell: Special Functions for Scientist's and Engineers, Dover Publications, 2004.
5. Sokolnikoff and Redheffer – Mathematics of Physics and Engineering. 2nd edition, McGraw Hill, 1967.
6. Ian Sneddon, Elements of Partial Differential Equations, McGraw Hill International, 1985.
7. Tychonov & Samarski: Partial Differential Equations of Mathematical Physics, Holden-Day, San Francisco , 1964.
8. B. Spain: Tensor Calculus, Oliver and Boyd, 1965.
9. J. Irving and N. Mullineux: Mathematics in Physics and Engineering, Academic Press, 1959.
10. Shepley L Ross, Differential Equations, JohnWiley & Sons, Third Edition, 2004.
11. L.A. Pipes and L.R. Harwill: Applied Mathematics for Engineers and Physicists, Mc Graw Hill, 1971.
12. M.A. Akivis and V.V Goldberg, An Introduction to Linear Algebra and Tensors, Dover Publications, 1997.

ME6401 ADVANCED ENERGY CONVERSION SYSTEMS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (12 hours)

Classification of energy sources - Utilization, economics and growth rates - Fossil fuels, nuclear fuels and solar energy - Combustion calculations - Conventional thermal power plant design and operation - Superheat, reheat and regeneration - Other auxiliaries of thermal plant - High-pressure boilers - Steam generator control.

Module II (10 hours)

Gas turbine and combined cycle analysis – Inter-cooling, 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.

Module III (10 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.

Module IV (10 hours)

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

ME6402 RENEWABLE ENERGY TECHNOLOGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module l (12 hours)

Solar energy – The Sun – Production and transfer of solar energy – Sun-Earth angles –Availability and limitations of solar energy – Measuring techniques and estimation of solar radiation – Solar thermal collectors – General description and characteristics – Flat plate collectors – Heat transfer processes – Short term and long term collector performance – Solar concentrators – Design, analysis and performance evaluation.

Module ll (10 hours)

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 – Performance and cost calculations – Special topics on solar energy.

Module lll (10 hours)

Energy from biomass – Sources of biomass – Different species – Conversion of biomass into fuels – Energy through fermentation – Pyrolysis, gasification and combustion – Aerobic and anaerobic bio-conversion – Properties of biomass – Biogas plants – Types of plants – Design and operation – Properties and characteristics of biogas.

Module lV (10 hours)

Wind energy – Principles of wind energy conversion – Site selection considerations –Wind power plant design – Types of wind power conversion systems – Operation, maintenance and economics – 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 Energy Thermal Processes*, J. Wiley, 1994
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. H.P. Garg, S.C. Mullick and A.K. Bhargava: *Solar Thermal Energy Storage*, 1985
6. K.M. Mittal: *Non-conventional Energy Systems-Principles, Progress and Prospects*, Wheeler Publications, 1997
7. G.D. Rai: *Non-conventional Energy Sources*, Khanna Publishers, 2003

EE6001 ELECTRICAL ENERGY SYSTEMS AND MANAGEMENT

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

Overall structure of electrical systems - Supply and demand side - Economic operation -Input-output curves - Load sharing - Industrial Distribution - Load profiling – Electricity tariff types and calculation - Reactive Power - Power factor - Capacitor sizing - Capacitor losses, location, placement and maintenance - Case studies.

Module I1 (11 hours)

Energy efficiency - Energy accounting, monitoring and control - Electricity audit instruments - Energy consumption models - Specific Energy Consumption – ECO assessment and Evaluation methods - Transformer loading/efficiency analysis – Feeder loss evaluation - Lighting - Energy efficient light sources - Domestic/commercial /industrial lighting - Lighting controls - Energy conservation in lighting schemes - Luminaries - Case studies.

Module I1I (11 hours)

Types and operating characteristics of electric motors - Energy efficient control and starting - Load matching - Selection of motors - Efficiency and load analysis – Energy efficiency - High efficiency motors - Industrial drives - Control schemes - Variable speed drives and Energy conservation schemes - Pumps and fans - Efficient control strategies - Over-sizing - Case studies.

Module IV (10 hours)

Electric loads of air conditioning and refrigeration - Energy conservation – Power consumption in compressors - Energy conservation measures - Electrolytic process - Electric heating - Furnace operation and scheduling - Cogeneration schemes – Optimal operation - Case studies - Computer controls - Softwares - EMS.

References

1. IEEE Bronze Book: IEEE Standard 739-1984 - *Recommended Practice for Energy Conservation and Cost Effective Planning in Industrial Facilities*, IEEE Publications, 1996
2. A. P.W. Thumann: *Plant Engineers and Managers Guide to Energy Conservation*, 7e, UNR, 1977
3. H. Partab, *Art and Science of Utilisation of Electrical Energy*, Pritam, 1985
4. S.C. Tripathy, *Electric Energy Utilization And Conservation*, Tata McGraw Hill, 1991
5. W.C. Turner, *Energy Management Handbook*, 2e, Fairmont Press, 1993
6. UNESCAP-Guide Book on *Promotion of Sustainable Energy Consumption* (www.unescap.org/enrd/energy)

ME6491 COMPUTATIONAL LABORATORY

L	T	P	C
0	0	3	1

1. Commercial Software Training

- Design, modeling and analysis (**I-DEAS)**
- Development of user friendly packages (**V-Studio)**
- Mathematical tools used in engineering (**MATLAB)**
- Computational fluid dynamics and heat transfer (**FLUENT)**

2. Programming Assignments on the Following Topics:

- Roots of algebraic and transcendental equations
- Solution of simultaneous algebraic equations
- Curve fitting and optimization
- Numerical integration and differentiation
- Numerical solution of ODEs: Initial value problems
- Numerical solution of ODEs: Boundary value problems
- Numerical solution of PDEs

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

ME6492 SEMINAR

L	T	P	C
0	0	3	1

Each student shall prepare a seminar paper on any topic of interest based on the core/elective courses being undergone in the first semester in the field of specialization – Energy Engineering. He/she shall get the paper approved by the Programme Coordinator/Faculty Advisor/Faculty Members in the concerned area of specialization and present it in the class in the presence of 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.

ME6411 FLUID FLOW AND HEAT TRANSFER IN ENERGY SYSTEMS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (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; Nondimensionalization 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 I (11 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.

Module III (10 hours)

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 IV (10 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, Second Edition, Narosa Publishing House, 2005.
2 D. Poulikakos: *Conduction Heat Transfer*, Prentice Hall, 1994
3. V.S. Arpaci: *Conduction Heat Transfer*, Addision Wesly, 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, 2007
6. M.F. Modest: *Radiative Heat Transfer*, McGraw Hill, 1993

ME6412 DESIGN AND ANALYSIS OF ENERGY SYSTEMS

Pre-requisite: Nil

Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

Engineering design fundamentals - Designing a workable system - Economic evaluation - Fitting data and solving equations - Design optimization - Knowledge based system design.

Module II (10 hours)

Heat exchanger design calculations - Evaporators and condensers temperature concentration pressure characteristics of binary solutions - Rectifiers - Cooling towers -Pressure drop and pumping power.

Module III (10 hours)

Pump characteristics - Manufacturer's specifications - Relations among performance characteristics - Pump system operation - Cavitation prevention - Other system considerations, Fans and nozzles.

Module IV (12 hours)

Basics of Second law analysis in heat and fluid flow - Applications in thermal design - Modeling and simulation principles - Hardy-Cross method - Multi-variable, Newton-Raphson simulation method - Simulation of a gas turbine system - Simulation using differential equations - Mathematical modeling of thermodynamic properties - Steady state simulation of large systems.

References

1. Y. Jaluria: *Design and Optimization of Thermal Systems*, Mc Graw Hill, 1998
2. A. Bejan: *Thermal Design and Optimization*, John Wiley, 1995
3. W.F. Stoeker: *Design of Thermal Systems*, 3e, Mc Graw 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. Jones J. B. and Dugan R. E.: Engineering Thermodynamics, Prentice Hall of India, 1998
7. Yunus A. Cengel: *Thermodynamics: An Engineering approach*, Mc Graw Hill, 1994
8. W.J. Gajda and W.E. Biles: *Engineering Modeling and Computation*, Houghton Mifflin, 1980

ME6413 ENERGY CONSERVATION IN THERMAL SYSTEMS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (11 hours)

Definition of energy management - Energy conservation schemes - Optimizing steam usage - Waste heat management - Insulation - Optimum selection of pipe size – Energy conservation in space conditioning - Energy and cost indices - Energy diagrams – Energy auditing - Thermodynamic availability analysis – Thermodynamic efficiencies - Available energy and fuel.

Module II (11 hours)

Thermodynamics and economics - Systematic approach to steam pricing - Pricing other utilities - Investment optimization - Limits of current technology - Process improvements - Characterizing energy use - Optimum performance of existing facilities - Steam trap principles - Effective management of energy use - Overall site interactions - Total site cogeneration potential - Linear programming approach.

Module III (10 hours)

Thermodynamic analysis of common unit operations - Heat exchange - Expansion - Pressure let down - Mixing - Distillation - Combustion air pre-heating – Systematic design methods - Process synthesis - Application to cogeneration system – Thermo-economics - Systematic optimization - Improving process operations – Chemical reactions - Separation - Heat transfer - Process machinery - System interaction and economics.

Module IV (10 hours)

Potential for waste heat recovery - Direct utilization of waste heat boilers – Use of heat pumps - Improving boiler efficiency - Industrial boiler inventory – Use of fluidized beds - Potential for energy conservation - Power economics - General economic problems - Load curves - Selections of plants - Specific economic energy problems - Energy rates.

References

1. W.F. Kenney: *Energy Conservation in the Process Industries*, Academic Press, 1984
2. A.P.E. Thummann: *Fundamentals of Energy Engineering*, Prentice Hall, 1984
3. M.H. Chiogioji: *Industrial Energy Conservation*, Marcel Dekker, 1979
4. A.P.E.Thummann, *Plant Engineers and Managers Guide to Energy Conservation*, van Nostrand, 1977
5. W. R. Murphy and G. McKay: *Energy Management*, Butterworth-Heinemann, 2001
6. F.B. Dubin: *Energy Conservation Standards*, McGraw Hill, 1978

ME6414 ENERGY AND ENVIRONMENT

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

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

Module II (11 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 III (10 hours)

Air Pollution Control methods and Water Pollution: Types of controls – Particulate emission control - Gaseous emission control - 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.

Module IV (10 hours)

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
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

ME6493 ENERGY ENGINEERING LABORATORY

L	T	P	C
0	0	3	1

Study and Experiments on Energy Systems from the Following List:

1. Heat Exchanger
2. Refrigeration Systems and heat pumps
3. Air-conditioning Coils
4. Heat pipes
5. Energy Efficient Chulah
6. Wind Energy System
7. Solar PV System
8. Solar Water and Air Heaters
9. Solar Still
10. Biomass Gasifiers
11. Fluidized Bed System
12. Waste Heat Recovery Systems

ME6494 TERM PAPER/MINI PROJECT/INDUSTRIAL TRAINING

L	T	P	C
0	0	0	1

Students are free to select any one assignment from the following term paper/mini project/industrial training.

Term Paper: Prepare a review paper on any topic in energy engineering with the individual analysis and comments.

Mini project: Students can select any project work and work under the guidance of any teaching staff in the department. End of the semester, each student has to submit a thesis report.
Project work is evaluated by the department as per M. Tech. regulations.

Industrial Training: Who are opting for industrial training, as to undergo a minimum of four weeks training in well established industries during in the summer vacation after the first two semesters. He has to submit a report on his training to the department and the same is evaluated as per M. Tech. regulations.

ME7495 PROJECT WORK

L	T	P	C
3	0	0	8

The student will be encouraged to fix 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 can be carried out at the institute or in an industry/research organization. They are supposed to complete a good quantum of the work in the third semester. There shall be evaluation of the work carried out in the third semester.

ME7496 PROJECT WORK

L	T	P	C
3	0	0	12

The project work started in the third semester will be extended to the end of the fourth semester. The project can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project in industry or other organization have to fulfill the requirements as specified in the "Ordinances and Regulations for M. Tech.". There shall be evaluations of the project work by a committee constituted by the department and by an external examiner.

Regulations for M. Tech. under the section - Project Work in Industry or Other Organization

At the end of the third semester, the students' thesis work shall be assessed by a committee and graded as specified in the "Ordinances and Regulations for M. Tech.". If the work has been graded as unsatisfactory, the committee may recommend a suitable period by which the project will have to be extended beyond the fourth semester. At the end of the fourth semester, the student shall present his/her thesis work before an evaluation committee, which will evaluate the work and decide whether the student may be allowed to submit the thesis or whether he/she needs to carry out additional work. The final viva-voce examination will be conducted as per the "Ordinances and Regulations for M. Tech."

ME6421 DIRECT ENERGY CONVERSION SYSTEMS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 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 - Applications.

Module II (10 hours)

Physics of solar photovoltaic cells - Production of solar cells - Design concept of PV cell systems - Solar cells connected in series and parallel - Voltage regulation and energy storage - Centralized and decentralized PV Systems - Maintenance of PV systems - Current developments.

Module III (12 hours)

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 IV (10 hours)

Definition, general description, types, design and construction of fuel cells - Thermodynamics of ideal fuel cells - Practical considerations - Present status - Future energy technologies - Hydrogen energy - Nuclear fusion.

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
7. N.B. Breiter: *Electro chemical Processes in fuel Cells*, Spring-Verlag, 1969
8. B. Viswanathan and M. Aulice 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**

ME6422 OPTIMAL DESIGN OF HEAT EXCHANGERS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (11 hours)

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

Module II (11 hours)

Direct sizing of heat exchangers - Plate fin exchangers - Exchanger lay up – 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.

Module III (10 hours)

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

Module IV (10 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

ME6423 ENERGY POLICIES FOR SUSTAINABLE DEVELOPMENT

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (11 hours)

Energy policies of India - 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.

Module II (11 hours)

Energy and environment - Green house effect - Global warming - Global scenario - Indian environmental degradation - Environmental laws - 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.

Module III (10 hours)

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 & trade scheme.

Module IV (10 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. IEEE Bronze Book: *Energy Auditing*, IEEE Publications, 1996
3. P. Chandra: *Financial Management Theory and Practice*, Tata McGraw Hill, 1992
4. *Annual Energy Planning Reports of CMIE*, Govt. of India
5. A.K.N. Reddy and A.S. Bhalla: *The Technological Transformation of Rural Inda*, UN Publications, 1997
6. A.K.N. Reddy, R.H. Williams and J.B. Johanson: *Energy After Rio-Prospects and Challenges*, UN Publications, 1997
7. P. Meier and M. Munasinghe: *Energy Policy Analysis & Modeling,* Cambridge University Press, 1993
8. R.S. Pindyck and D.L. Rubinfeld*: Economic Models and Energy Forecasts,* 4e, McGraw Hill, 1998

ME6424 FLUIDIZED BED SYSTEMS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 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.

Module II (12 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.

Module III (10 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.

Module IV (9 hours)

Fluidized bed heat exchangers - Fluidized bed furnaces and boilers - Fluidized bed steam generator for liquid metal fast breeder reactor - Pressurized fluidized bed combustion boilers - Pressurized adiabatic and pressurized air tube fluidized bed combustion.

References

1. J.R. Howard: *Fluidized Bed Technology, Principles and Applications*, Adam Hilger, 1989
2. D. Kunii and O. Levenspiel: *Fluidization Engineering*, J. Wiley, 1986
3. J.F. Davidson and D. Harrison: *Fluidization*, Academic Press, 1971

ME6425 HEAT PUMP TECHNOLOGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9 hours)

Heat pump theory - Types of heat pump systems - Typical heat pump arrangements - Efficiency comparisons - Heat pump-refrigeration cycles - Comparison of water-source and air-source heat pumps.

Module II (11 hours)

Heat pump components - Compressor types and performance - Heat transfer components - Expansion and metering devices - Reversing values, filters, drier and accumulator - Auxiliary heating elements - Refrigerant piping and pipe insulation - Various control and wiring circuits - Part-load performance of components.

Module III (12 hours)

Design of heat pump systems - Proper selection of working fluid - Compressor and prime movers - Heat pump performance evaluation - Seasonal performance factor - Comparison of solar assisted heat pumps - Applications of heat pump systems - Reliability and maintenance of heat pumps.

Module IV (10 hours)

Advances in heat pumps - Improvements and innovations - Advanced cycles for vapor absorption 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. H.J. Saner Jr and R.H. Howell: *Heat pump systems*, J. Wiley, 1983
2. D.A. Reay and D.B.A. Maemichael: *Heat Pumps - Design and Application*, Pergamon, 1979
3. M.J. Collie (ed): *Heat Pump Technology for Saving Energy*, Noyes Data Corp, 1979
4. B.C. Langley: *Heat Pump Technology - System Design, Installation and Troubleshooting,* 2e, Prentice Hall, 1989
5. Summer School Notes on *Heat Pump Technology*, I.I.T. Madras, 1990

ME6426 MICRCHANNEL FLOW AND MIXING ANALYSIS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	1	0	3

Module I (10 hrs)

Introduction – Physics at the micrometric scale – Miniaturization of systems – Hydrodynamics of micro-fluidic systems – Interface phenomena in micro-fluidics – Diphasic flows and emulsions in Microsystems.

Module II (10 hrs)

Electro hydrodynamics in microsystems – Electro-osmosis and electrophoresis in micro-channels – Effect of surface heterogeneity on electro-kinetic flow – Experimental studies of electro-osmotic flow – Electrophoretic motion of particles in micro-channels.

Module III (11 hrs)

Diffusion, mixing and separation in Microsystems – 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 Microsystems.

Module IV (11 hrs)

Special topics in micro-fluidics – Thermalization of heat source in Microsystems - 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. Em. Karniadakis, and A. Beskok N. Aluru: Micro flows and Nanoflows– Fundamentals and Simulation, Springer 2005.
3. D. Li. 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.

ME6427 ENERGY EFFICIENT BUILDINGS

Pre-requisite: Nil

Total Hours: 42

L	T	P	C
3	0	0	3

Module I (11 hrs)

Climate and shelter – Historic buildings – Modern architecture – Examples from different climate zones – Thermal comfort – Solar geometry and shading – Heating and cooling loads – Energy estimates and site planning – Integrative Modeling methods and building simulation.

Module II (10 hrs)

Principles of Energy conscious building design – Energy conservation in buildings – Day lighting – Water heating and photovoltaic systems – Advances in thermal insulation – Heat gain/loss through building components – Solar architecture.

Module III (10 hrs)

Passive solar heating – Direct gain – thermal storage wall – Sunspace – Convective air loop – Passive cooling – Ventilation - Radiation – Evaporation and Dehumidification – Mass effect – Design guidelines.

Module IV (11 hrs)

Energy conservation in building – Air conditioning – HVAC equipments – Computer packages for thermal design of buildings and performance prediction – Monitoring and instrumentation of passive buildings – Control systems for energy efficient buildings – Illustrative passive buildings – Integration of emerging technologies – Intelligent building design principles.

References

1. J. A. Clarke, Energy Simulation in Building Design (2e) Butterworth 2001.
2. J. K. Nayak and J. A. Prajapati Hadbook on Energy Consious 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.

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

ME6428 INTEGRATED ENERGY SYSTEMS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hrs)

Energy consumption pattern – Projection of energy demands – Possible substitution of conventional sources – Modern technological options – Introduction to hybrid and integrated energy systems – Total energy concept and waste heat utilization.

Module II (11 hrs)

Modeling of Integrated energy systems – Load matching and scheduling – Various possibilities to build hybrid systems – Problems associated with integrated energy systems – Performance analysis.

Module III (11 hrs)

Optimal design of hybrid energy systems – Special optimization techniques applicable – Energy economics and cost optimization of integrated energy systems – Sample problems and case studies.

Module IV (10 hrs)

Integration of various power generation systems – Feasibility studies – Site selection – Related social, economic and technical problems – Special role of wind and biogas systems – Future prospects and case studies.

References

1. P. R. Shukla, T. K. Moulik, S. Modak and P. Deo; Strategic Management of Energy Conservation, Oxford & IBM Publishing Co., 1993.
2. W. R. Murthy and G. McKay; Energy Management, Butherworth Heinemann, 2001.
3. S. S. Rao; Textbook on Engineering Optimization – Theory and Practice, 3rd Edition, J. Wiley, 1996.
4. R. D. Begamudre: Energy Conversion Systems, New Age Int. Pub., 2000.
5. D. Merick and R. Marshall; Energy, Present and Future Options, Vol. I & Vol. II, J. Wiley, 1981.

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

ME6429 THEORY OF COMBUSTION

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hrs)

Introduction: Chemical thermodynamics: Heat of reaction and formation. Free energy and equilibrium constants. Flame temperature and its calculation.

Chemical kinetics: Rates of reactions, temperature dependence. Simultaneous independent reactions, chain reactions. Pseudo first order reactions. Partial equilibrium assumptions, pressure effect.

Module II (11 hrs)

Explosive and general oxidative characteristics of fuels : Chain branching reactions, criteria for explosions. Explosion limits and oxidation characteristics of Hydrogen, carbon monoxide and hydrocarbons. Flame phenomena in premixed combustible gases: Laminar flame speed, stability limits of laminar flames. Turbulent flames

Module III (10 hrs)

Introduction to detonation phenomena. Hugoniot theory and hydrodynamic theory of detonation. ZND structure of detonation waves. Diffusion flames: Appearance, structure and theoretical considerations. Gaseous fuel jets, burning of condensed phases, droplet clouds.

Module IV (11 hrs)

Ignition, chain spontaneous ignition, thermal spontaneous ignition, Semenov approach of thermal ignition. Forced ignition, spark ignition and minimum ignition energy. Ignition by adiabatic compression and shock waves. Environmental combustion considerations. Nature of photochemical smog, formation and reduction of nitrogen oxides. Sox emission and particulate formation.

References

1 Irvin Glassman, *Combustion*, Academic Press, Third Edition 1996.
2. Warnatz, J., Maas, U., and Dibble, R. W., *Combustion: Physical and Chemical Fundamentals, Modelling and Simulation, Experiments, Pollutant Formation*, Fourth Edition, Springer: Berlin, 2006.
3. Turns R S, An *Introduction to Combustion*, McGrawHill, New York, 1996.
4. Kuo K K, *Principles of Combustion*, Second Edition, Wiley, New York, 2005.
5. Zel'dovich, Y. B., and Razier, Y. P., *Physics of Shock Waves and High-Temperature Hydrodynamic Phenomena*, Dover, New York, 2002.

ME 6430 ADVANCED AIR BREATHING PROPULSION

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hrs)

Introduction: Propulsion, units, operational envelopes and standard atmosphere, air-breathing engines, aircraft performance, rocket engines.

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.

Module II (11 hrs)

Principles of air breathing propulsion, performance parameters, ramjet engine: Cycle and performance analysis, supersonic inlets, combustors for liquid fuel ramjet engines, combustion instability and its suppression, solid fuel ramjet engines, testing of ramjets.

Module III (10 hrs)
Ramrockets: Performance analysis, ducted and shrouded types, air-augmented rockets, integrated ramjet-rocket systems, nozzle less solid propellant rockets and integrated ramjet-rocket boosters, dump combustors and associated combustion problems, computational fluid dynamics techniques in the design and development of combustors.

Module IV (11 hrs)

Hypersonic air-breathing propulsion, SCRAM jet engines: Methods of analysis, hypersonic intakes, supersonic combustors, engine cooling and materials problem, CFD applications, liquid air-cycle engines, space plane applications, experimental and testing facilities, the shock tunnel.

References

1. Jack D. Mattingly, *Elements of Propulsion, Gas Turbines and Rockets*, AIAA Education Series 2006.
2. George P.Sutton and Oscar Biblarz, *Rocket Propulsion Elements*, Wiley-Interscience, 7th Edition, 2000.
3. Philip Hill and Carl Peterson, *Mechanics and Thermodynamics of Propulsion*, Prentice Hall, 7th Edition, 2000.
4. E T Curran and SNB Murthy, *Scramjet Propulsion*, AIAA, 2000.
5. William H. Heiser and David.D.Pratt, *Hypersonic Air breathing propulsion*, AIAA, 1993.

ME6431 CRYOGENIC ROCKET PROPULSION SYSTEMS

Pre-requisite: Nil

Total Hours: 42

L	T	P	C
3	0	0	3

Module I (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 II (10 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 III (11 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 IV (11 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

ME6432 ENVIRONMENTAL ENGINEERING AND POLLUTION CONTROL

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 hours)

INTRODUCTION: 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 II (11 hours)

AIR POLLUTION: 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 III (11 hours)

WATER POLLUTION: 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

Module IV (10 hours)

POLLUTION FROM INDUSTRIES AND INSTRUMENTATION: 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 (2003): Introduction to Environmental Engineering and Science, Prentice Hall of India Pvt Ltd, New Delhi.
4. H.S. Peavy, D.R. Rowe, G. Tchobanoglous (1985): Environmental Engineering -McGraw- Hill Book Company, New York.
5. H. Ludwig, W. Evans (1991): Manual of Environmental Technology in Developing Countries, International Book Company, Absecon Highlands, N.J.
6. Arcadio P Sincero and G. A. Sincero, (2002): Environmental Engineering – A Design Approach, Prentice Hall of India Pvt Ltd, New Delhi.
7. J. Rau and D.C. Wooten: *Environmental Impact Analysis Handbook*, McGraw Hill, 1980

ME6433 EMERGING REFRIGERATION TECHNOLOGIES

Pre-requisite: Nil

L	T	P	C
3	0	0	3

Module I (10 hours)

Introduction to refrigeration systems, methods of refrigeration, units of refrigeration, COP, Review of vapour compression refrigeration system, vapour absorption system, Introduction to nonconventional refrigeration technologies- Thermoelectric refrigeration, magnetic refrigeration, pulse tube refrigeration, acoustic refrigeration, steam jet refrigeration, vortex tube refrigeration.

Module II (10 hours)

Thermoelectric refrigeration-principle, thermoelectric properties, Seabeck effect, Peltier effect, System description, performance, analysis, Applications

Module III (10 hours)

Introduction to Magnetic refrigeration, magneto-caloric effect, magnetic materials, magnetic refrigeration near room temperature cooling, advantages over traditional refrigeration system, clean refrigeration in future-pulse tube refrigerator-principle-analysis

Module IV (12 hours)

Principles and application of steam jet refrigeration system, Performance, vortex tube refrigeration system, system description, Applications

Modern refrigerants **-** Need for alternative refrigerants – eco friendly refrigerants - properties of mixtures of refrigerants-modifications required for retrofitting, safety precautions and compatibility of refrigerants with the materials.

References

1 Arora C.P Refrigeration and Air conditioning-Tata Mc Graw Hill, 2004
2 Gosney W. B Principles of Refrigeration, Cambridge University Press, 1983
3 Stanley W Angrist Direct Energy conversions 1982
4 HJ Goldsmid Thermoelectric Refrigeration 1964

ME6434 HYDROGEN - PRODUCTION, STORAGE AND TRANSPORTATION

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module 1 (11 Hrs)
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, Note of Caution.
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. High-temperature electrolysis.
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 II (11 Hrs)
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 Petroleum and Coal and organic compounds. Cracking, Reforming of Natural Gas. Characteristics of 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

Module III (10 Hrs)
Gas Separation: Gas Separation Processes. Membrane Types, Membrane Developments for Gas Separation, Membrane Reactors, Gasification Technology, Entrained-flow Gasifier, Moving-bed Gasifier, Fluidized-bed Gasifier.
Storage: 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.

Module IV (10 Hrs)
Transportation, Distribution and Storage, 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. Alvise Perosa, Fulvio Zecchini, and Pietro Tundo Methods and Reagents for Green Chemistry: An Introduction Wiley Inter science 2007
7. The Solar Hydrogen Civilization, Roy McAlister, www.knowledgepublications.com
8. Solar Hydrogen Energy, John O'M. Bockris, T. Nejat Veziroglu, Debbi Smith, MacDonald Optima, London, U.K., 1991
9. The Hydrogen Economy, Jeremy Rifkin, www.amazon.com
10. Our Future is Hydrogen: Energy, Environment, and Economy, Robert Siblerud, www.amazon.com
11. Tomorrow's Energy:Hydrogen,Fuel Cells,and Prospects for a Cleaner Planet, Peter Hoffmann, www.amazon.com
12. Carbon Nanomaterials in Clean Energy Hydrogen Systems, Baranowski, B.; Zaginaichenko, S.Y.; Schur, D.; Skorokhod, V.; Veziroglu, A. (Eds.), www.springer.com
13. Hydrogen Fuel: Production, Transport, and Storage, Ram B. Gupta, www.crcpress.com
14. The Hydrogen Economy: Opportunities and Challenges, Michael Ball and Martin Wietschel, www.cambridge.org

ME6435 HYDROGEN ENERGY CONVERSION TECHNOLOGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (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 100 years. Hydrogen energy chain: Transport, Stationary power, Portable power and Other applications. Environmental concerns, cost, Examples and pilot programs, Hydrogen prize.

Module II (14 Hrs)

Hydrogen as a fuel in Heat engines: in 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 - Car, Buses. Fuel supply system and emission studies 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 combustion* **Engines. 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 III (8 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.

Module IV (10 Hrs)

Traction mechanisms: Used for Fuel cell operated, Comparison with Pure battery operated, Combo drives: Battery & fuel cell, Battery & Hydrogen cum Gasoline engine, Fuel cell & Hydrogen cum Gasoline engine.
Metering, instrumentation and safety issues: EMS, safety issues, Instrumentation in H2 usage. leak detectors used in production, transport and conversion, Hydrogen sniffer leak detection solution. Problems in hydrogen usage: hydrogen embrittlement, hydrogenation of oils

References

1. Arno A. Evers (2010). The Hydrogen Society. Hydrogeit Verlag. ISBN 978-3-937863-31-3.
2. Jeremy Rifkin (2002). The Hydrogen Economy. Penguin Putnam Inc. ISBN 1-58542-193-6.
3. Roy McAlister (2003). The Solar Hydrogen Civilization. American Hydrogen Association. ISBN 0-9728375-0-7.
4. Joseph J. Romm (2004). The Hype about Hydrogen, Fact and Fiction in the Race to Save the Climate. Island Press. ISBN 1-55963-703-X. Author interview at Global Public Media.
5. James Howard Kunstler (2006). The LONG EMERGENCY. Grove Press. ISBN 0-8021-4249-4. Hydrogen economy = "laughable a fantasy" p. 115
6. M. Wang (2002). "Fuel Choices for Fuel Cell Vehicles: Well-to-Wheels Energy and Emissions Impact". Journal of Power Sources 112: 307–321. doi:10.1016/S0378-7753(02)00447-0.
7. F. Kreith (2004). "Fallacies of a Hydrogen Economy: A Critical Analysis of Hydrogen Production and Utilization". Journal of Energy Resources Technology 126: 249–257. doi:10.1115/1.1834851.
8. Nakicenovic, et al. (1998). Global Energy Perspectives. Cambridge University Press. Summary
9. National Research Council (2004). The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs. National Academy Press. This book is available online in full text: [5].
10. Novelli, P.C., P.M. Lang, K.A. Masarie, D.F. Hurst, R. Myers, and J.W. Elkins. (1999). "Molecular Hydrogen in the troposphere: Global distribution and budget". J. Geophys. Res. 104(30): 427–30.
11. T. K. Tromp (2003). "Potential Environmental Impact of a Hydrogen Economy on the Stratosphere". Science 300: 1740–1742. doi:10.1126/science.1085169. PMID 12805546

12. Lawrence W. Jones, Toward a liquid hydrogen fuel economy, University of Michigan engineering technical report UMR2320, 1970.
13. J. Larminie and A. Dicks, Fuel Cell Systems Explained, 2nd Edition, Wiley (2003)
14. Xianguo Li, Principles of Fuel Cells, Taylor and Francis (2005)
15. S. Srinivasan, Fuel Cells: From Fundamentals to Applications, Springer (2006)
16. O'Hayre, S. W. Cha, W. Colella and F. B. Prinz, Fuel Cell Fundamentals, Wiley (2005)
17. PEM FUEL CELLS, Frano Barbir, www.amazon.com
18. Fuel Cells: Problems and Solutions, Vladimir S. Bagotsky, www.electrochem.org
19. The Hydrogen Energy Transition Moving Toward the Post Petroleum Age in Transportation
20. Edited by: Daniel Sperling and James S. Cannon
21. Elsevier Inc. 2004, ISBN: 978-0-12-656881-3
22. Hydrogen Energy Technologies, T. Nejat Veziroglu and Frano Barbir, UNIDO Emerging Technologies Series, UNIDO, Vienna, 1998
23. Fuel Cell Engines, Matthew M. Mench, www.amazon.com

ME6436 ENERGY MODELING, ECONOMICS AND PROJECT MANAGEMENT

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (12 Hrs)

Models and modeling approaches: input output analysis, energy demand analysis and forecasting, economics of stand alone power supply systems, project management. Macroeconomic Concepts-Measurement of National Output-Investment Planning and Pricing -Economics of Energy Sources - Reserves and Cost Estimation. Multiplier Analysis-Energy and Environmental Input/Output Analysis-Energy Aggregation-Econometric Energy Demand Modeling-Overview of Econometric Methods. Methodology of Energy Demand Analysis-Methodology for Energy Technology Forecasting-Methodology for Energy Forecasting-Sectoral Energy Demand Forecasting. Solar Energy-Biomass Energy-Wind Energy and other Renewable Sources of Energy - Economics of Waste Heat Recovery and Cogeneration-Energy Conservation Economics. Cost Analysis-Budgetary Control-Financial Management-Techniques for Project Evaluation.

Module II (10 Hrs)

Basic concept of econometrics and statistical analysis: The 2-variable regression model; The multiple regression model; Tests of regression coefficients and regression equation; Econometric techniques used for energy analysis and forecasting with case studies form India; Operation of computer package Input – Output Analysis, Basic concept of Input-output analysis; concept of energy multiplier and implication of energy multiplier for analysis of regional and national energy policy; Energy and environmental Input - Output analyses using I-O model

Module III (10 Hrs)

Energy Modeling: Interdependence of energy-economy-environment; Modeling concept, and application, Methodology of energy demand analysis; Methodology for energy forecasting; Sectoral energy demand forecasting; Interfuel substitution models; SIMA model, and I-O model for energy policy analysis; Simulation and forecasting of future energy demand consistent with macroeconomic parameters in India; Energy Economics and Policies: National and Sectoral energy planning; Integrated resource planning; Energy pricing

Module IV (10 Hrs)

Project Evaluation & Management: Financial analysis: Project cash flows, time value of money, life cycle approach & analysis, conception, definition, planning, feasibility and analysis; Project appraisal criteria; Risk analysis; Project planning matrix; Aims oriented project planning; Social cost benefit analysis. Network analysis for project management; Time estimation; Critical path determination; PERT, CPM and CERT; Fuzzy logic analysis; Stochastic based formulations; Project evaluation techniques; Funds planning; Project material management, evaluation & analysis; Implementation and monitoring; Performance indices; Case studies.
2 Autonomous Fossil Fuel and renewable energy (RE)-based Power Systems

References

1. Energy Policy Analysis and Modeling, M.Munasinghe and P.Meier Cambridge University Press 1993
2. (1987): The Econometrics of Energy Demand: A Survey of Applications, W.A.Donnelly New York 1987.
3. Econometrics Models and Economic Forecasts, S.Pindyck and Daniel L.Rubinfeld, 3rd edition MC Graw -Hill, New York. 1991
4. Sectoral Energy Demand Studies: Application of the END-USE Approach to Asian Countries, UN-ESCAP, New York 1991.
5. Guide Book on Energy -Environment Planning in Developing Countries- Methodological Guide on Economic Sustainability and Environmental Betterment Through Energy Savings and Fuel Switching in Developing Countries, UN-ESCAP, New York 1996
6. Forecasting Methods and Applications, S.Makridakis , Wiley 1983

ME6437 HYDROPOWER SYSTEMS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 Hrs)

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. 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 II (10 Hrs)

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 III (10 Hrs)

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.

Module IV (10 Hrs)

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

1. Principles of Turbo machinery, Shepherd D.G., Macmillan Company, Newyork,1956
2. Hydraulic Turbines, Krevichenko, MIR Publishers
3. Micro Hydro Electric Power Station(1984), L.Monition,M.Lenir and J.Roux
4. Micro Hydro Power Source Book(1986), AlenR. Inversin
5. Power Plant Evaluation and Design (1988), Tyler G.Hicks

   websites:

   1. http://www.digiserve.com/inship
   2. http://www.siemens.de
   3. www.tva.gov/power

ME6438 INFORMATION TECHNOLOGY IN ENERGY MANAGEMENT

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (10 Hrs)

The need for software engineering in energy management. Survey of software life cycle models software engineering, Introduction to computer application, IT system, database management system, computer based monitoring and online control system.

Module II (10 Hrs)

Programming languages - Introduction to Visual C++, C Programming Design - Computer Organization.

Module III (10 Hrs)

Types of CBIS - Relationship among CBIS system concepts and CBIS - general systems theory - Energy Management concepts and CBIS. Intelligence based system - energy data bases - networking - time sharing concepts.

Module IV (10 Hrs)

Transform theory of software performance - network model of structured programs. Data acquisition systems - expert based systems for energy management – Parallel Processing Concepts - Typical applications in energy management area.

References

1. C/C++ Programmer's reference Herbert Schildt, McGraw-Hill, New York 2000.
2. Rapid Application Development with Visual C++(1999), David McMahon, McGraw-Hill, New York.
3. Computer Architecture:Concepts and Evolution, Gerrit Blaauw, Frederick Brooks, Addison Wesley 1997
4. Software Engineering, Ian Sommerville, 5/e, University of Lancaster, England (1996), Addison Wesley.
5. Software Engineering, Pressman, Addison Wesley
6. Introduction to Expert Systems, Peter Jackson, 3/e, addison Wesley(1998).
7. Databases: Design, Development and Deployment with student CD (Pkg), Peter Rob McGraw-Hill, New York (1999).

Websites:
1. http://www.emd.dk
2. http://www.esd.uk
3. www.energymanagementsys.com

ME6439 RECENT ADVANCES IN REFRIGERANTS

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (9hrs)

Refrigeration cycles and role of the refrigerants in the refrigerating system: Refrigeration cycles – representation in p-h, T-s coordinates - theoretical and practical cycles - losses in refrigeration system, subcooling, superheating and components of the system – role of refrigerant in the system – commercially used refrigerants.

Module II (8hrs)

Types of refrigerants: Primary and secondary refrigerants – examples, natural refrigerants, organic and inorganic refrigerants, chloro flurocarbons, hydro flurocarbons, hydrofluroethers.
Mixed refrigerants – mixture behavior: azeotropic, zeotropic, and near azeotropic.

Module III (12hrs)

Properties of refrigerants: Thermodynamic properties – boiling point, freezing point, critical pressure, critical temperature, condenser and evaporator pressures, coefficient of performance, power per ton.
Thermo physical properties - thermal conductivity, viscosity, surface tension, latent heat of vapourization, specific heat in both the phase.
Chemical properties – Toxicity, flammability, reaction with materials of components, reaction with oils.
Environmental properties – Ozone layer depletion, Global warming potential.
Selection of refrigerants for specific applications.

Module IV (10hrs)

Alternative refrigerants: Need for alternative refrigerants – ecofriendly refrigerants - Preparation of mixtures of refrigerants - analysis of properties of mixtures - performance of CFC12, HCFC22 alternatives - modifications required for retrofitting, safety precautions and compatibility of refrigerants with the materials.

References

1. W.F. Strocker and Jones, 1981. Refrigeration and air conditioning. McGrawhill publishers. New Delhi.
2. Jordon and Prister, 1985. Refrigeration and air conditioning. Printence Hall of India
3. Althouse AD, Turnquist. 1985. Morern refrigeration and air conditioning. Good heart-Wilcox co Inc.
4. R.J. Dossat, 1997. Principles of refrigeration. Pearson Education.
5. K.E. Herold, R. Radermancher and S.A. Klein, 1996. Absorption chillers and heat pumps, CRC press London.
6. Goshnay WB. 1982. Principles of refrigeration Cmbridge University press.
7. C.P. Arora, 2001. Refrigeration and air conditioning. Tata Mcgraw Hill publishers. New Delhi.
8. M. Prasad. 2001. Refrigeration and air conditioning. New age publishers. New Delhi.
9. S.C. Arora and Domkundwar 2001. Refrigeration and air conditioning. Dhanpat Rai Publishing Company, New Delhi.

Journals

1. International Journal of Refrigeration
2. Applied Thermal Engineering
3. ASHRAE Transactions
4. International Journal of Energy research
5. International Journal of Applied Thermal Engineering

Hand books

1. ASHRAE hand book of fundamentals 1972.
2. ASHRAE Handbook of systems 1973.

Websites

www.brazewag.com/refrigeration
www.iifir.org
www.suva.dupont.ca/

Software

1. REFPROP 7. National institute of standards and technology (NIST).

ME9401 RESEARCH METHODOLOGY

Pre-requisite: Nil
Total Hours: 42

L	T	P	C
3	0	0	3

Module I (11 hrs)

Research design - Need for research design - Features and concepts of good design - Different research designs - Basic principles of experimental designs - Steps in sampling design - Characteristics of good sampling design - Different types - Random samples - Complex random sampling design- Important sampling distributions- Central limit theorem - Sampling theory - Concept of standard error – Estimation - Estimating the population mean and proportion - Sample size an its determination.

Module II (10 hrs)

]Methods of data collection - Primary data - Observation method - Interview method – Questionnaires – Schedules - Collection of secondary data - Processing and analysis of data - Processing operations - Some problems in processing - Types of analysis - Statistics in research - Measures of central tendency - Measures of dispersion - Measures of asymmetry - Measures of relationship - Simple regression analysis - Multiple correlation and regression - Partial correlation - Association in case of attributes.

Module III (10 hrs)

Hypothesis - Testing of hypothesis – Procedure - measuring the power of a hypothesis test - Test of hypothesis - important parametric tests - Hypothesis testing of means- Hypothesis testing for difference between means - Hypothesis testing for comparing two related samples - Hypothesis testing of proportions - Hypothesis testing for difference between proportions - Hypothesis testing for comparing a variance to some hypothesized population variance - Testing the equality of variances of two normal populations.

Module IV (11 hrs)

Chi-square tests - Conditions for application of Chi-square test and steps involved - Important non-parametric/distribution free test - Relationship between Spearman's r's and Kendall's W - characteristics of non-parametric tests - Multivariate analysis techniques - Characteristics and applications - Classification of multivariate techniques - Variables in multivariate analysis - Important multivariate techniques - Important methods of factor analysis - Rotation in factor analysis - R-type & Q-type factor analysis.

References

1. Kothari, C.R. "Research Methodology - Methods and Techniques", New Age International (P) Limited, New Delhi, 1990.
2. John, P.W.M. "Statistical Design and Analysis of Experiments", Macmillan Co., New York, 1971.
3. Ghosh, B.N., "Scientific Methods and Social Research", Sterling Publishers (P) Limited, New Delhi, 1982.