# DEPARTMENT OF MECHANICAL ENGINEERING

**Detailed Syllabi for the M.Tech. Programme in**

## ENERGY MANAGEMENT

## First Semester

| MAG604 MATHEMATICAL METHODS |
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**Module I: Linear Algebra (10 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 Theory (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 (10 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 and mixed tensors , fundamental operation with tensors, 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. K. Hoffman and R. Kunze: Linear Algebra P. H. I., 1971.
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 Differntial 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.

## MED601 ENERGY CONVERSION SYSTEMS

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**Module I (10 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 (9 hours)**

Gas turbine and combined cycle analysis – Inter-cooling, reheating and regeneration -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

## MED602 ALTERNATIVE ENERGY UTILISATION

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**Module l (11 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 (9 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

## EEG601 ELECTRICAL ENERGY SYSTEMS AND MANAGEMENT

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**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 (10 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 (10 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 (9 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)

## MED691 COMPUTATIONAL LABORATORY

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**A. Hands-on Training on the Following Softwares:**

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

**B. 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 integration of ordinary differential equations: Initial value problems
- Numerical Solution of ordinary differential equations: Boundary value problems
- Numerical solution of partial differential equations

**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


## MED692 SEMINAR I

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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 Management. 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.

## Second Semester

### MED611 DESIGN AND ANALYSIS OF ENERGY SYSTEMS

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**Module I (9 hours)**

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

**Module II (8 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

## MED612 ENERGY CONSERVATION IN THERMAL SYSTEMS

| L | T | P | C |
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**Module I (10 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 (10 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 (9 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

## MED613 ENERGY AND ENVIRONMENT

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**Module I (9 hours)**

**Energy Overview:** 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 analysis - Basic process of water treatment - Primary treatment - Secondary treatment - Advanced treatment.

**Module IV (9 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

## MED614 HEAT TRANSFER IN ENERGY SYSTEMS

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**Module I (8 hours)**
Review of conservative laws - Review of constitutive relations - Differential formulation of general heat transfer problems - Types of boundary conditions - Homogeneous equations and boundary conditions.

**Module II (9 hours)**
Conductive heat transfer in energy systems - Practical examples including nuclear reactors, solar thermal collectors, heat exchangers, energy storage systems, etc.

**Module III (9 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 (13 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. D. Poulikakos: *Conduction Heat Transfer*, Prentice Hall, 1994
2. V.S. Arpaci: *Conduction Heat Transfer,* Addision Wesly, 1996
3. H.S. Carslaw and J.C. Jaeger: *Conduction of Heat in Solids*, Oxford University Press, 1959
4. A. Bejan: *Convection Heat Transfer*, J. Wiley, 1984
5. W.M. Kays and M.E. Crawford: *Convection Heat and Mass Transfer*, 2e, McGraw Hill, 1980
6. M.F. Modest: *Radiative Heat Transfer*, McGraw Hill, 1993
7. E.M. Sparrow and R.D. Cess: *Radiation Heat Transfer*, Hemisphere, 1978
8. W.A. Gray and R.Miller: *Engineering Calculation in Radiation Heat Transfer*, McGraw Hill, 1959

## MED693 ENERGY MANAGEMENT LABORATORY

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**Study and Experiments on Energy Systems from the Following List:**

1. Heat Exchanger
2. Refrigeration Systems
3. Air-conditioning Coils
4. Heat pipe
5. Energy Efficient Chulah
6. Wind Energy System
7. Solar PV System
8. Solar Water Heater
9. Solar Still
10. Biomass Gasifier
11. Fluidized Bed System
12. Waste Heat Recovery Systems

## MED694 SEMINAR II

| L | T | P | C |
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Each student shall prepare a seminar paper on any topic of interest based on the core/elective courses being undergone in the second semester in the field of specialization – Energy Management. 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.

## MED621 OPTIMAL DESIGN OF HEAT EXCHANGERS

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**Module I (11 hours)**

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

**Module II (10 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 (9 hours)**

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

**Module IV (9 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

## MED622 ADVANCED INSTRUMENTATION

| L | T | P | C |
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**Module I (8 hours)**

Measurements of thermal and physical properties - Viscosity - Use of poiseuille flow, Falling, Rotating and Oscillating bodies - Thermal conductivity of solids and liquids - Low conductivity and metallic - Steady and unsteady states - Measurement of specific heat of gases - Data acquisition - Analog and digital conversion - Post processing of data - Statistical analysis - Goodness of data - Correlating data - Linear and non-linear regression.

**Module II (12 hours)**

Error estimates in Temperature measurements - Solids and fluids - Steady state and unsteady measurements - Radiation effects - Platinum resistance thermometers - Construction and usage - Calibration - Bridges - Fluid pressure measurement - Capacitive probes - Piezoelectric pressure sensors - Anemometry.

**Module III (10 hours)**

Thermal radiation measurements - Radiometry - Surface radiation measurements - Gas radiation instruments - Errors in radiation measurements - Transient experimental techniques for surface heat flux rates - Negligible internal resistance - Negligible surface resistance - Rapid response measurements - Thick film and thin film gauges - Non uniform surface temperatures - Quasi steady measurements.

**Module IV (10 hours)**

Temperature Measurements in high temperature gases - Calorimetric, electrostatic, radiation, cyclic, transient pressure and heat flux probes - Spectroscopic methods - Cooled film sensors - Temperature measurement in cryogenics - Scales of measurement-Thermocouple, resistance and magnetic thermometry - Optical measurement of temperature - Schlieren shadow-graph and interferometer - Errors in optical measurements.

**References**


1. E.R.G. Eckert and R.J. Goldstein: *Measurements in Heat Transfer*, McGraw Hill, 1976
2. J.P. Holman: *Experimental Methods for engineers*, McGraw Hill, 1971
3. E.O. Doebelin: *Measurements Systems: Application and Design*.
4. T.G. Beekwith and L.M. Buck : *Mechanical measurements*, Adison-Wesley, 1965
5. Barney: *Intelligent Instrumentation*, Printice Hall, 1988

## MED623 ENERGY POLICIES FOR SUSTAINABLE DEVELOPMENT

| L | T | P | C |
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**Module I (10 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.

**Module II (10 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.

**Module III (9 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.

**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. Energy Planning Reports of CMIE, State Governments & Govt. of India

## MED624 DIRECT ENERGY CONVERSION

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**Module I (9 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 (8 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 V (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

## MED625 FLUIDIZED BED SYSTEMS

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**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.

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**Module II (10 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

## MED626 HEAT PUMP TECHNOLOGY

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**Module I (8 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 (10 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 (9 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

## Third and Fourth Semesters

### MED795 COMPREHENSIVE VIVA

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Each student is required to appear for the Comprehensive Viva-Voce examination. This is an oral examination based on the courses (Theory, Laboratory and Seminars) undergone by the student in the first and second semester M. Tech. Programme in Energy Management.

### MED796 PROJECT

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The project work starts in the third semester and extends to the end of the fourth semester. The student will be encouraged to fix the area of work and conduct the literature review during the second semester itself. The topic shall be research and development oriented. 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. 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.".