M.Tech. SOLAR ENERGY (FULL TIME)
CURRICULUM AND SYLLABUS
2013 – 2014

FACULTY OF ENGINEERING AND TECHNOLOGY
SRM UNIVERSITY
SRM NAGAR, KATTANKULATHUR – 603 203
SRM UNIVERSITY

DEPARTMENT OF MECHANICAL ENGINEERING

M.Tech. SOLAR ENERGY (FULL TIME)

CURRICULUM AND SYLLABUS

Eligibility:

B. E. / B. Tech. (Mechanical Engineering/Automobile Engineering / Chemical Engineering / Electrical and Electronics Engineering) / M. Sc. (Physics)

**Duration:** 2 years in 4 semesters

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<th>Type of course</th>
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**Total credits to be earned for the award of M.Tech degree – 71 credits**

Total number of credits to be earned for the award of M.Tech degree: 71

**CORE COURSES**
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**CONTACT HOUR/CREDIT:**

L: Lecture Hours per week  T: Tutorial Hours per week
P: Practical Hours per week  C: Credit
CORE COURSES

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<tr>
<th>ME2401</th>
<th>SOLAR RADIATION AND ENERGY CONVERSION</th>
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Total Contact Hours-75

Prerequisites
Nil

PURPOSE
To familiarize students with the characteristics of solar radiation, its global distribution, and conversion methods of solar energy to heat and power.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students will be able to understand and apply

1. The characteristics and world distribution of solar radiation.
2. The solar radiation and measurement techniques.
3. The methods of calculation of solar radiation availability at a given location.
4. The fundamentals of thermal and direct conversion of solar energy to power.

UNIT I - ENERGY RESOURCES AND SOLAR SPECTRUM
(15 hours)

UNIT II - SOLAR RADIATION AND MEASUREMENT
(15 hours)
UNIT III- SOLAR RADIATION GEOMETRY AND CALCULATIONS  
(15 hours)

UNIT IV - SOLAR THERMAL ENERGY CONVERSION  
(15 hours)

UNIT V - SOLAR ELECTRICAL ENERGY CONVERSION (15 hours)

REFERENCES

ME2402 HEAT TRANSFER IN SOLAR SYSTEMS  
Total Contact Hours-75

Prerequisites
Nil

PURPOSE
To familiarize the students with the heat transfer processes to design and analyze the solar thermal systems.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to understand

1. The heat transfer processes by conduction.
2. The heat transfer processes by convection.
3. The radiation heat transfer.
4. Phase change heat exchangers and heat exchanger.
5. The numerical methods of heat transfer.

UNIT I – CONDUCTION     (15 hours)
One dimensional energy equations and boundary conditions – Three dimensional conduction equations - Extended surfaces – Critical thickness of insulations – Overall heat transfer coefficient.

UNIT II - TURBULENT FORCED CONVECTIVE HEAT TRANSFER      (15 hours)

UNIT III – RADIATION     (15 hours)
UNIT IV - PHASE CHANGE HEAT TRANSFER AND HEAT EXCHANGERS  
(15 hours)
Condensation and boiling – Pool and flow boiling, solidification and melting. Heat exchanger - ε - NTU approach and design procedure, compact heat exchanger.

UNIT V - NUMERICAL HEAT RANSFER  
(15 hours)

REFERENCE BOOKS

PURPOSE
To familiarize students with the concepts of control and drives, importance of embedded system and implementation of control system for solar energy applications.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to understand and apply

1. The basic concepts of process control and controllers.
2. Electronic realization of controllers.
3. Modeling of process using MATLAB.
4. Embedded system and automation.
5. Advanced controls in solar plants.

UNIT I - CONTROLLER PRINCIPLES  (15 hours)
Basic concepts of process control, discontinuous and continuous mode operation. Introduction to proportional, integral and derivative control. Controller design, characteristics and feedback compensation. Response of controllers.

UNIT II - ELECTRONIC REALIZATION  (15 hours)
Pneumatic and electronic realization of controllers. Selection of controllers, need for process controller, controller tuning and evaluation criteria. P/I and I/P converters.

UNIT III - MODEL REPRESENTATION  (15 hours)
Introduction to MATLAB, matrix operation, different graphical output, integration and solution to differential equation. Types of error - Convergence and stability. Models of electro-mechanical system – Thermo-
fluid systems, solar photo voltaic cell and DC motor. Transient and steady state response of system. Simulation of model using MATLAB.

**UNIT4 - EMBEDDED SYSTEM AND APPLICATION** (15 hours)
Introduction to Embedded system - Design cycle and 8051 microcontroller requirement, challenges, trends and issues. Use of emulator and in-circuit emulator. Applications of Embedded system in control system and automation, handheld computer, IVR system and GPS receivers.

**UNIT V - CONTROL OF SOLAR PLANTS** (15 hours)
Basic and Advanced control of solar plants- basic control algorithms, adaptive and optimal controls. Model based predictive control strategies, frequency domain control and robust optimal control. Introduction to fuzzy logic control and LABVIEW - Current trends in instrumentation.

**REFERENCE BOOKS**

ME2404 INSTRUMENTATION AND CONTROL IN ENERGY SYSTEMS

Total Contact Hours-75

Prerequisites

Nil

PURPOSE
To study the working principle of various instruments and control devices used in energy systems.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able

1. To familiarize with the characteristics of instruments.
2. To familiarize with the thermal and fluid flow measurements systems.
3. To understand the flow visualization techniques.
4. To understand the computer automated measurements and controls.
5. To understand the applications of microprocessor and microcontrollers.

UNIT I - CHARACTERISTICS OF INSTRUMENTS (15 hours)
Instruments - Classification – Characteristics – Static and dynamics - Systematic and random errors -Statistical analysis - Uncertainty - Selection and reliability. Data logging and acquisition - Intelligent instruments - Physical variables - Error reduction.

UNIT II - THERMAL AND FLUID FLOW MEASUREMENTS (15 hours)
Measurement of temperature, pressure and flow- Gas analyzers-measurement of smoke, dust and moisture, pH-gas chromatography-spectrometry-Review of basic measurement techniques.

UNIT III - FLOW VISUALIZATION (15 hours)
Flow visualization techniques, shadowgraph, schileren, interferometer, LDA, heat flux measurement, telemetry in energy systems.
UNIT IV – TRANSDUCERS (15 hours)

UNIT V - MICROPROCESSORS (15 hours)
Microprocessor based temperature control system – Introduction to microcontrollers – Process control system – Pneumatic control systems - Simple circuits.

REFERENCE BOOKS


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**Total Contact Hours-75**

Prerequisites
Nil

PURPOSE
To familiarize the students with principles of operation, structure, testing and installation of major types of solar thermal collectors.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to
1. Understand the fundamentals of solar flat plate collectors.
2. Analyze the performance of solar flat plate collectors.
3. Understand the fundamentals of concentrating solar collectors.
4. Analyze the performance of concentrating solar collectors.
5. Familiar with the solar low, medium and high temperature applications.

COURSE DESCRIPTION

UNIT I - SOLAR FLAT PLATE COLLECTORS (15 hours)
Fundamentals of solar collectors as devices to convert solar energy to heat. Non-concentrating low temperature flat-plate and evacuated tube collectors. Design and structures of collectors for heating liquids and air.

UNIT II - PERFORMANCES OF FLAT PLATE COLLECTORS (15 hours)
Optimal collector tilt and orientation. Collector performance - Useful energy gain, energy losses, efficiency. Use of selective coatings to enhance the collector efficiency. Concentrating collectors for middle and high temperature applications.

UNIT III - SOLAR CONCENTRATING COLLECTORS (15 hours)
Line-focusing and point-focusing concentrators: parabolic trough, parabolic dish, heliostat field with central receiver, Fresnel lenses, compound parabolic concentrator. Sun tracking mechanisms.

UNIT IV - PERFORMANCE OF SOLAR CONCENTRATORS (15 hours)
Concentrating collector performance - concentration ratio, useful energy gain, energy losses, efficiency. Solar collector design, testing, installation and operation.

UNIT V- APPLICATIONS OF SOLAR COLLECTORS (15 hours)
Application of non-concentrating collectors in low temperature solar thermal plants for space heating and cooling, drying, seawater desalination. Use of concentrating collectors for process heat production and power generation.
REFERENCE BOOKS


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<td>ME2401 Solar radiation and energy conversion</td>
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PURPOSE
To study fundamentals and application of solar thermal systems for heating, cooling, power generation and other applications.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students will be able to understand and apply

1. The knowledge on solar passive heating and cooling.
2. The fundamentals of design calculations and analysis of solar thermal systems.
3. The functioning and design of solar thermal cooling systems.
4. The basics of solar thermal technology for process heating
5. The fundamentals of design calculations and economics of solar power generation.

UNIT I- SOLAR PASSIVE HEATING AND COOLING (15 hours)

UNIT II - SOLAR LIQUID AND AIR HEATING SYSTEM (15 hours)

UNIT III - SOLAR COOLING AND DEHUMIDIFICATION (15 hours)

UNIT IV - SOLAR THERMAL APPLICATIONS (15 hours)

UNIT V - SOLAR THERMAL POWER PLANTS (15 hours)
REFERENCE BOOKS


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PURPOSE
To learn the fundamentals, design and application of solar photovoltaic systems for power generation on small and large scale electrification.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to understand and apply

1. The principle of direct solar energy conversion to power using PV technology.
2. The structure, materials and operation of solar cells, PV modules, and arrays.
3. The concept to design PV systems for various applications.
4. The socio-economic and environmental merits of photovoltaic systems for a variety of applications.
5. The prospects of photovoltaic technology for sustainable power generation.

UNIT I - SOLAR CELL FUNDAMENTALS (15 hours)
Photovoltaic effect - Principle of direct solar energy conversion into electricity in a solar cell. Semiconductor properties, energy levels, basic equations. Solar cell, p-n junction, structure.

UNIT II - PV MODULE PERFORMANCE (15 hours)
I-V characteristics of a PV module, maximum power point, cell efficiency, fill factor, effect of irradiation and temperature.

UNIT III - MANUFACTURING OF PV CELLS & DESIGN OF PV SYSTEMS (15 hours)
Commercial solar cells - Production process of single crystalline silicon cells, multi crystalline silicon cells, amorphous silicon, cadmium telluride, copper indium gallium di selenide cells. Design of solar PV systems and cost estimation. Case study of design of solar PV lantern, stand alone PV system - Home lighting and other appliances, solar water pumping systems

UNIT IV - CLASSIFICATION OF PV SYSTEMS AND COMPONENTS (15 hours)
Classification - Central Power Station System, Distributed PV System, Stand alone PV system, grid Interactive PV System, small system for consumer applications, hybrid solar PV system, concentrator solar photovoltaic. System components - PV arrays, inverters, batteries, charge controls, net power meters. PV array installation, operation, costs, reliability.

UNIT V - PV SYSTEM APPLICATIONS (15 hours)
Building-integrated photovoltaic units, grid-interacting central power stations, stand-alone devices for distributed power supply in remote and rural areas, solar cars, aircraft, space solar power satellites. Socio-economic and environmental merits of photovoltaic systems
REFERENCE BOOKS


ELECTIVE COURSES

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PURPOSE
This course provides the knowledge of modern materials science and engineering to solar energy applications.

INSTRUCTIONAL OBJECTIVES
After completion of this course, students are able to understand the

2. Properties of various materials and special coatings and applications.
3. Testing of materials behavior suitable for application in solar energy systems.
4. Environmental impact on solar system materials and corrosion protection.
UNIT I - FUNDAMENTAL PRINCIPLES OF MATERIALS SCIENCE
(9 hours)
Electronic and atomic structures, atomic bonding in solids, crystal structure, microstructure, solidification, alloys. Mechanical and electrical behavior of ceramics. Description of optical and thermal materials of concrete and composite materials. Intrinsic and extrinsic semi-conductors, super conductivity and applications.

UNIT II - PROPERTIES OF MATERIALS
(9 hours)
Mechanical, photonic, thermal electrical and magnetic properties of metals, alloys, semiconductors, polymers, glass, nanomaterials and magnetic materials. Environmental effects - corrosion, erosion, wind loads, thermal stress and weathering properties of solar materials.

UNIT III - TESTING OF MATERIALS
(9 hours)
Concepts of stress and strain, Hooke’s law, tension, compression and shear. Stress-strain diagram and thermal stresses. Elasticity in metals and polymers, plastic deformation, yield stress, shear strength, strengthening mechanisms, effect of temperature, fracture behavior of various materials, failure analysis, solid solutions and phase diagrams.

UNIT IV - MATERIALS FOR SOLAR THERMAL SYSTEMS
(9 hours)
Design and development of heat transfer systems - Domestic community and commercial solar thermal applications. Design considerations of solar collectors, special coatings, reflectors, lenses, receivers, tracking and non-tracking concentrator, thermal energy storage, heat exchangers, solar chimney, solar steam generators, solar ponds and solar still, solar dryer and furnace.

UNIT V - MATERIALS FOR SOLAR PHOTOVOLTAICS
(9 hours)
Characteristics of solar photovoltaic cell, modules, batteries, inverters, charge controller, supporting structures. Construction of SPV collector, array and fields. Cost analysis and payback calculations of solar panels and collectors.

REFERENCES
India, 2009.

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Total Contact Hours - 45
Prerequisites
Nil

PURPOSE
To familiarize the students with design methods of solar thermal and photovoltaic systems.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to

1. Understand the design concepts of solar systems.
2. Design and development of solar thermal systems.
3. Design of photovoltaic system and its components.
4. Analyze the performance of solar energy systems.

UNIT I - DESIGN CONCEPTS OF SOLAR SYSTEMS (9 hours)
System conceptual design, design of major components, overall system, design of physical principles to the solar system based on application. The process includes idea generation, concepts election and estimation, design of major components, and overall system design, solar radiation data.

UNIT II - SOLAR HEATING AND COOLING SYSTEMS (9 hours)
Design of solar thermal systems for water, space heating, cooling and power generation. f-Chart calculation method for sizing solar water and space heating systems. Design of non-focusing and focusing collectors.
UNIT III - SOLAR THERMAL ENERGY STORAGE (9 hours)
Design aspects of solar thermal energy storage systems. Selection criteria of storage materials for heating and cooling applications, selection of heat transfer fluid for heating and cooling applications. Design of LHTES for solar process heating and power generation applications.

UNIT IV - SOLAR PHOTOVOLTAIC SYSTEM (9 hours)
Design of photovoltaic off-grid and grid-connected power systems. Design of system components - PV modules, batteries, charge controllers, inverters, auxiliaries. Performance analysis of a photovoltaic system. Using software codes for design of solar thermal and photovoltaic systems.

UNIT V - PERFORMANCE ANALYSIS (9 hours)
Performance analysis of various solar thermal systems, PV system and evaluation of solar thermal energy storage system, selection of components and materials, estimation of economics. Using software tools for design of solar thermal and photovoltaic systems, case studies.

REFERENCES

PURPOSE
To familiarize the students with the methods of modeling and analysis of solar thermal and PV systems.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to understand and apply the

1. Mathematical modeling development methods.
2. Quantitative techniques.
3. Various numerical methods to solve equations.
4. Software tools to solve problems.
5. Energy optimization techniques.

UNIT I - MATHEMATICAL MODELING (9 hours)
Mathematical modeling overview – Types, stages, choosing the modeling equations, levels of analysis, steps in model development, solving and testing of models.

UNIT II - QUATITATIVE TECHNIQUES (9 hours)
Quantitative techniques – Interpolation - Polynomial, Lagrangian curve fitting, regression analysis and solution of transcendental equations.

UNIT III - NUMERICAL METHODS (9 hours)

UNIT IV - SOFTWARE TOOLS (10 hours)
Overview of effective tools for solar energy systems - RET Screen -
Evaluation of the energy production and savings of renewable energy and energy efficient technologies, TRNSYS - Dynamic simulation of solar heating and cooling systems, GREENIUS - Simulation, design and analysis of solar thermal electric and photovoltaic systems, PVSYST - Sizing, simulation and analysis of photovoltaic systems.

UNIT V - ENERGY OPTIMIZATION (8 hours)
Case studies of energy system optimization – Application - Analysis and design of solar thermal and photovoltaic systems.

REFERENCES


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Prerequisites
Nil

PURPOSE
To study the principles of structural analysis and its application to solar energy system structures.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are
1. Familiar with the concepts and principles of structural analysis.
2. Able to apply the structural analysis in solar energy system structure design.
3. Able to perform the wind load calculation for solar energy system structures.

UNIT I - CONCEPTS OF STRENGTH OF MATERIALS (9 hours)

UNIT II - PRINCIPLE OF STRUCTURES (9 hours)

UNIT III - STRUCTURAL ANALYSIS (9 hours)

UNIT IV - ANALYSIS OF FRAMES, TRUSSES AND COMPOSITE STRUCTURES (9 hours)

UNIT V - WIND LOADS (9 hours)
Wind load on building structures, wind load on solar collectors and PV panels mounted on the roof. Barriers - Varieties of materials and air barrier configuration.
REFERENCES


<table>
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<tr>
<th>ME2415</th>
<th>NANOMATERIALS FOR SOLAR APPLICATIONS</th>
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Prerequisites
Nil

PURPOSE
This course provides the knowledge of nanomaterials and their applications in solar engineering.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students will be familiar with

1. The properties of nanomaterials and nanostructures.
2. Nanomaterials in solar energy conversion devices and systems.
3. The use of nanostructures and nanomaterials in solar energy storage.
4. The use of nanomaterials in the fuel cell and hydrogen technology.

UNIT I - PROPERTIES OF NANOMATERIALS (9 hours)
Introduction to nanomaterial, nano dimensional materials, classification of nanomaterials, bulk materials and nanomaterials – changes in bulk and

UNIT II - NANOMATERIALS FOR SOLAR THERMAL CONVERSION
(9 hours)
Conversion of thermal energy - Nanostructures and nanomaterials, materials selection criteria, particle-scale effect. Phase compositions on nanoscale microstructures. Nanoparticles for conduction heat transfer, coatings on fins.

UNIT III - NANO APPLICATIONS IN THERMAL ENERGY STORAGE
(9 hours)

UNIT IV - NANOMATERIALS FOR PHOTOVOLTAICS
(9 hours)

UNIT V - NANOMATERIALS IN FUEL CELL APPLICATIONS
(9 hours)
Use of nanostructures and nanomaterials in fuel cell technology - high and low temperature fuel cells, cathode and anode reactions, fuel cell catalysts, electrolytes, ceramic catalysts. Use of nano technology in hydrogen production and storage.

REFERENCES


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<tr>
<th>ME2416</th>
<th>ENERGY CONSERVATION AND MANAGEMENT</th>
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**PURPOSE**
To familiarize the students with energy conservation and management.

**INSTRUCTIONAL OBJECTIVES**
Upon successful completion of the course the students are able to understand the
1. Energy conservation principles.
2. Energy conservation in thermal systems.
3. Energy conservation in electrical systems.
4. Basic concepts of energy management.

**UNIT I - ENERGY CONSERVATION PRINCIPLES** (9 hours)
UNIT II - ENERGY CONSERVATION IN THERMAL SYSTEMS
(9 hours)
Energy conservation in thermal utilities like boilers, furnaces, pumps and fans, compressors, cogeneration - steam and gas turbines. Heat exchangers, lighting system, motors, belts and drives, refrigeration system.

UNIT III - ENERGY CONSERVATION IN ELECTRICAL SYSTEMS
(9 hours)
Electrical Systems - Demand control, power factor correction, load scheduling and shifting, motor drives, motor efficiency testing, energy efficient motors and motor speed control. Demand side management - Electricity Act, lighting efficiency options, fixtures, day lighting, timers and energy efficient windows.

UNIT IV THERMAL ENERGY CONSERVATION
(9 hours)
Case studies of Commercial/ Industrial/ Residential thermal energy conservation systems and their economical analysis.

UNIT V ENERGY MANAGEMENT
(9 hours)

REFERENCES

ME2417 | ENERGY EFFICIENT BUILDINGS AND SYSTEMS | L | T | P | C
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Prerequisite
Nil

**PURPOSE**
This course provides an introduction to the energy efficient building design, construction, operation and its economics.

**INSTRUCTIONAL OBJECTIVES**
Upon successful completion of the course the students are able to understand and apply

1. The concepts and techniques of energy efficient buildings and solar house design features.
2. The concepts and techniques of solar passive heating and cooling systems.
3. The concepts and techniques of day lighting and electrical lighting, heat control of buildings.
4. The design concepts of energy efficient buildings.

**UNIT I - ENERGY TRANSFER IN BUILDINGS** (9 hours)

**UNIT II - PASSIVE SOLAR HEATING AND COOLING** (9 hours)
General principles of passive solar heating – Key design elements - Direct solar heat gain trombe walls, water walls, convective air loops, concepts and case studies. General principles of passive cooling, ventilation, predicting ventilation in buildings, window ventilation calculations. Reradiation – Evaporative cooling, mass effect, thermal insulation, load control, air filtration, odor removal and heat recovery in large buildings.
UNIT III - DAYLIGHTING AND ELECTRICAL LIGHTING

(9 hours)

UNIT IV - HEAT CONTROL AND VENTILATION

(9 hours)

UNIT V - GREEN BUILDINGS

(9 hours)

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**PURPOSE**
To study the fundamentals of thermal storage, phase change materials, thermal analysis of various models and application of thermal storage in heating and cooling.

**INSTRUCTIONAL OBJECTIVES**
Upon successful completion of this course the students will be able to understand and apply
1. The techniques used for storing various forms of energy.
2. The design and analysis techniques used for various thermal storage systems.
3. The concepts and design of TES and using PCM materials.
4. The techniques used for storing thermal energy in heating and cooling applications.

**UNIT I - ENERGY STORAGE**  
(8 hours)  
Energy storage - Utilization of energy storage devices, specific areas of applications of energy storage, selection of types of energy to be stored, types of storage system. Thermal energy storage - Necessity, types, comparison of thermal energy storage technologies - Seasonal thermal energy storage.

**UNIT II - ANALYSIS OF THERMAL STORAGE MODELS**  
(12 hours)  
Single-blow operating mode - Infinite fluid heat capacity, negligible temperature gradient in storage material, internal temperature gradient in storage material, simplified model. Finite conductivity model-slab
configuration, hollow cylinder, comparisons of finite conductivity models of hollow cylindrical and slab configurations, analysis of the effects of finite thermal conductivity.

UNIT III - MODELING OF LHTES SYSTEMS (12 hours)

UNIT IV - STORAGE MATERIALS AND HEAT TRANSFER FLUIDS (6 hours)
Thermal energy storage materials - Classification, thermo physical properties, selection criteria. Phase change materials – classifications, properties, selection for heating and cooling applications. Heat transfer fluids - Properties, selection of heat transfer fluid for heating and cooling applications.

UNIT V - THERMAL STORAGE APPLICATIONS (7 hours)
Cool storage concept - Comparison of storage technologies, cool thermal storage in process cooling and building air conditioning systems. Solar energy storage – Passive heating and cooling, green house heating – Drying and heating for process industries - Solar power plant applications.

REFERENCES


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Total Contact Hours-45

**Prerequisites**
Nil

**PURPOSE**
To study the various research methodologies, analysis and report writing.

**INSTRUCTIONAL OBJECTIVES**
Upon successful completion of the course the students are able to

1. Understand the research preparation and planning.
2. Understand various data collection methods.
3. Study various sampling methods.
4. Perform various sampling tests.
5. Prepare effective report.

**UNIT I - RESEARCH PREPARATION AND PLANNING** (9 hours)
Research methodology - Definition, mathematical tools for analysis. Types of research - exploratory research, conclusive research, modeling research and algorithmic research. Research process steps.

**UNIT II - DATA COLLECTION METHODS** (9 hours)
Data collection method - Primary data - Observation method, personal interview, telephonic interview, mail survey and questionnaire design. Secondary data- Internal sources of data, external sources of data. Scales - Measurement.

**UNIT III - SAMPLING METHODS** (9 hours)
Sampling methods - Probability sampling methods, simple random sampling with and without replacement, stratified sampling, cluster sampling. Non- probability sampling method - convenience sampling, judgment sampling and quota sampling.
UNIT IV- SAMPLING TESTS  (9 hours)
Hypotheses testing - Testing of hypotheses, concerning variance - one tailed Chi-square test, nonparametric tests, one sample tests, one sample sign test, Kolmogorov-Smirnov test, run test for randomness, two sample tests, two sample sign test, Mann-Whitney U test, K-sample test - Kruskal Wallis test (H-Test).

UNIT V - ANALYSIS AND REPORTING  (9 hours)
Introduction to discriminant analysis, factor analysis, cluster analysis, multidimensional scaling and conjoint analysis. Report writing - types of reports, guidelines to review report, typing instructions and oral presentation.

REFERENCES

PURPOSE
This course provides the knowledge of energy economics, policy and energy auditing.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to understand and apply

1. The basics of energy economics.
2. The economic analysis of energy system.
3. The renewable energy technology development priorities.
4. The concepts and methods of energy economics to solar energy systems.
5. The energy policy and security aspects of energy.

UNIT I - FINANCIAL AND ECONOMIC PERFORMANCE (9 hours)
Introduction to financial and economic performance - Merits and limitations for solar energy projects - time value of money, benefits/cost ratios, discount rate, standard and discount payback period, depreciation and net present benefit - Uncertainty over financial incentives-Methods for financing solar energy projects-regulations, legislation, cultural aspects and maintenance issue.

UNIT II - ECONOMIC ANALYSIS (9 hours)
Elements of economic principle, economic calculation. Energy economics-basic concepts, unit cost of power generation from different sources, payback period, NPV, IRR and benefit cost analysis. Conventional and solar energy resources and costs. Direct and indirect costs, pricing system and project management.
UNIT III - ENERGY TECHNOLOGY DEVELOPMENT PRIORITIES  
(9 hours)
Significance of renewable energy sources for sustainable economic development. Economics of solar energy system. Increase in value creation. Funding and sponsoring facilities, international organizations, national possibilities. Incentives, subsidies and feed-in traffic.

UNIT IV - ENERGY MANAGEMENT  
(9 hours)
Socio-economics, basic needs and ethics. Ecological issues, sustainable energy for future and carbon credit. Energy auditing and management. Conservation of thermal and electrical energy in buildings and various industries.

UNIT V - ENERGY POLICY AND SECURITY  
(9 hours)

REFERENCES

PURPOSE
This course provides the knowledge of working principles of conventional power generation and the importance of renewable energy sources.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to understand
1. The operating principles and components of steam and nuclear power plant.
2. The operating principles and components of hydro, gas turbine power plants.
3. The solar and wind energy conversion systems.
4. The biomass, tidal and geothermal power plants.
5. The operating principles of hydrogen energy, fuel cells and MHD power generation.

UNIT I - STEAM AND NUCLEAR POWER GENERATION (10 hours)
Steam power plant - Selection of site - Generated layout - coal and ash handling - Steam generating plants - Feed make circuit - Cooling towers - Turbine governing, plant performance enhancement techniques, advanced technologies for coal-fired power plants, supercritical and ultra-supercritical steam power plants, power plant major and auxiliary equipment. Nuclear power plants – Classification - Nuclear Fuels.

UNIT II - HYDRO, GAS TURBINE AND COMBINED CYCLE PLANTS (9 hours)
Hydro power plant - Selection of Site - Classification layout governing of turbines - Gas turbine power plants - Performance enhancement techniques, equipment, combined cycle power plants, integrated gasification combined cycle, cogeneration plant - Equipment and performance.
UNIT III - SOLAR AND WIND ENERGY (10 hours)

UNIT IV - BIOMASS, TIDAL AND GEOTHERMAL ENERGY SOURCES (9 hours)

UNIT V- HYDROGEN, FUEL CELL AND MHD POWER (7 hours)
Hydrogen, generation, storage, transport and utilization and transport. Fuel cell technology – Types, power generation and economics. MHD power generation – Principle, classification, design problems and developments.

REFERENCES
PURPOSE
To study the principles and applications of computational fluid dynamics.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to understand the

1. Governing equations of CFD and formulations using FEM.
2. Finite volume formulations applicable to flow problems.
3. Solution methods present in finite difference method.
4. Techniques in turbulence modeling.
5. Grid generation techniques for fluid flow problems.

UNIT I - GOVERNING EQUATIONS (9 hours)

UNIT II - FINITE VOLUME METHOD (9 hours)
Finite volume formulation- 1D, 2D and 3D problems - Convection and diffusion problems - Laplace equation - Poisons equation - Parabolic equation. Properties of discretisation schemes - Central differencing schemes, upwind schemes, hybrid schemes and quick schemes.

UNIT III - SOLUTION METHODS (9 hours)
UNIT IV - TURBULENCE MODELING (9 hours)
Importance, significance and types - Prandl-mixing length model - One equation model, K-ε model, RSM equation model – Applications.

UNIT V - GRID GENERATION TECHNIQUE (9 hours)

REFERENCES

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Total Contact Hours-45

Prerequisite

Nil

PURPOSE
To familiarize the students about the Indian and Global energy scenario.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to
1. Understand the various sources of energy.
2. Understand energy consumption and impact of energy on economy.
3. Have clear idea about environmental policies.
4. Knows energy policy and energy scenario.
5. Have clear idea about the alternate source of energy.

UNIT I - ENERGY RESOURCE (9 hours)
Energy resources – Conventional and non-conventional sources of energy - Fossil fuels, solar, wind and biomass sources. Global and Indian energy scenario - Potential and power generation.

UNIT II - WORLD ENERGY SUPPLY AND DEMAND (9 hours)
Economic and energy consumption growth rate. Technology development and innovation. Global energy intensity - Oil prices and alternative sources. Strategies to achieve desired energy scenario – Research, development, demonstration and deployment, energy intensity reduction, Government policies and International collaboration.

UNIT III - ENVIROMENTAL POLICY (9 hours)
Pollution - Power generation and utilization. Energy forecasting, impact on environment – CO\textsubscript{2} emission reduction - Environmental policies.

UNIT IV- SUSTAINABLE DEVELOPMENT (9 hours)
Sustainable development of renewable and non renewable energy sources. Future energy options - Energy crisis, transition from carbon rich and nuclear to carbon free technologies, parameters of transition.

UNIT V - ENERGY POLICY (9 hours)

REFERENCES

5. Mohan Munasinghe and Peter Meier., “Energy policy modeling and


<table>
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<tr>
<th>ME2424</th>
<th>ENVIRONMENTAL IMPACT OF ENERGY SYSTEMS</th>
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**PURPOSE**
To familiarize the students in the area of Environmental impact of energy systems.

**INSTRUCTIONAL OBJECTIVES**
Upon successful completion of the course the students are able to understand

1. The environmental impacts and degradation due energy production and utilization.
2. The causes of different types of pollution and their impact assessment.
3. The pollutions from different types of power plants.
4. The concept of waste management and control.
5. The concept of carbon credits for environmental protection.

**UNIT1 - ENVIRONMENTAL IMPACTS**
Environmental impacts - Environmental degradation due to energy production and utilization.

**UNIT II – POLLUTION**
Primary and secondary pollution, air, thermal and water pollution, depletion of ozone layer, global warming, biological damage due to environmental degradation. Methods of environmental impact assessment.

**UNIT III - POLLUTION FROM POWER PLANTS AND ITS CONTROL**
Pollution - Pollution due to thermal power station and its control and systems. Pollution due to nuclear power generation, radioactive waste and its disposal, effect of hydro electric power stations on ecology and environment.
UNIT IV - WASTE MANAGEMENT AND POLLUTION CONTROL

(9 hours)

Waste as a source of energy - Industrial, domestic and solid waste as a source of energy. Pollution control - Causes process and exhaust gases and its control, mechanism and devices for pollution control.

UNIT V - ENVIRONMENTAL PROTECTION AND CARBON CREDITS

(9 hours)

Global environmental concern - United Nations framework convention on climate change (UNFCC), protocol, conference of parties (COP), clean development mechanism (CDM), prototype carbon funds, carbon credits and trading, benefits to developing countries, building a CDM project.

REFERENCES

ME2425 FUEL CELL AND HYDROGEN TECHNOLOGY

Total Contact Hours-45

Prerequisite Nil

PURPOSE
To study the basics of fuel cell and hydrogen technologies and their applications.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to understand and apply
1. The methods of hydrogen production, storage and utilization.
2. The basics of fuel cell technology.
3. The major types of fuel cells and their modes of operation.
4. The application of fuel cells in power cogeneration and heat and power cogeneration.

UNIT I - HYDROGEN PRODUCTION STORAGE AND UTILIZATION (9 hours)

UNIT II - FUEL CELL TECHNOLOGY (9 hours)
Fuel cell electrochemistry - Reaction rate - Butler Volmer equation-implications and use of fuel cell polarization curve - Conversion of chemical energy in electricity in a fuel cell.

UNIT III - FUEL CELL AND MODES OF OPERATION (9 hours)
Type of fuel cells, fuel cell working principle – Design - Proton exchange membrane fuel cells - Design issues - High temperature fuel cells - SOFC-MCFC - Comparison of fuel cell - Performance characteristics - Efficiency of leading fuel cell types.
UNIT IV - APPLICATION OF FUEL CELLS IN POWER COGENERATION (9 hours)

UNIT V - FUEL CELL RESEARCH (9 hours)

REFERENCES


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PURPOSE
This course provides the knowledge of cogeneration and waste heat recovery systems and also enables the students to analyze the techno economic viability of various energy systems.

INSTRUCTIONAL OBJECTIVES
Upon successful completion of the course the students are able to understand and apply
1. The basic thermodynamic principles of cogeneration.
2. The cogeneration technologies based on steam turbine, gas turbine and IC engine.
3. The issues and applications of cogeneration technologies.

UNIT I - BASIC CONCEPTS OF COGENERATION (9 hours)

UNIT II - COGENERATION TECHNOLOGIES (9 hours)
Configuration and thermodynamic performance – Cogeneration systems based on steam turbine, gas turbine, combined cycle and IC engine. Advanced cogeneration systems - Fuel cell and Stirling engines.

UNIT III - APPLICATIONS AND ENVIRONMENTAL CONSIDERATIONS (9 hours)

UNIT IV - WASTE HEAT RECOVERY SYSTEMS (9 hours)

UNIT V - ECONOMIC ANALYSIS (9 hours)
REFERENCES


SUPPORTIVE COURSES

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PURPOSE

To develop analytical capability and to impart knowledge in Mathematical and Statistical methods and their applications in Engineering and Technology and to apply these concepts in engineering problems they would come across.

INSTRUCTIONAL OBJECTIVES

At the end of the course, Students should be able to understand Mathematical and Statistical concepts and apply the concepts in solving the engineering problems.

UNIT I INITIAL AND BOUNDARY VALUE PROBLEMS

Classification of Linear differential equation - solution of initial and boundary value problems. Laplace transform methods for one - dimensional wave equation - Displacements in a string. Fourier series methods for one dimensional wave equation and one - dimensional heat conduction problems.
UNIT II PROBABILITY (9 hours)
basic definition, conditional, Probability, Baye's theorem - Binomial, Poisson, Normal, Exponential, Rectangular, Gamma Distributions. Moment generating function, random variables, two dimensional random variables.

UNIT III PRINCIPLE OF LEAST SQUARES (9 hours)
Fitting of Straight line and parabola - Correlation - Linear multiple and partial correlation - Linear regression - Multiple regression.

UNIT IV SAMPLING DISTRIBUTIONS (9 hours)
Tests based on t-distribution, chi-square and F-distributions - Analysis of variance - One-way and two-way classifications.

UNIT V TIME SERIES ANALYSIS (9 hours)

REFERENCES

MA2007 APPLIED MATHEMATICS FOR MECHANICAL ENGINEERS

Total contact hours - 45

Prerequisite
Nil

PURPOSE
To develop analytical capability and to impart knowledge in Mathematical and Statistical methods and their applications in Engineering and Technology and to apply these concepts in engineering problems they would come across.

INSTRUCTIONAL OBJECTIVES
At the end of the course, Students should be able to understand Mathematical and Statistical concepts and apply the concepts in solving the engineering problems.

UNIT I TRANSFORM METHODS (9 hours)
Laplace transform methods for one-dimensional wave equation - Displacements in a string - Longitudinal vibrations of an elastic bar - Fourier transform methods for one-dimensional heat conduction problems in infinite and semi-infinite rod.

UNIT II ELLIPTIC EQUATIONS (9 hours)
Laplace equation - Fourier transform methods for Laplace equation - Solution of Poisson equation by Fourier transform method.

UNIT III CALCULUS OF VARIATIONS (9 hours)
Variation and its properties - Euler's equation - Functionals dependent on first and higher order derivatives - Functionals dependent on functions of several independent variables - Some applications - Direct methods - Ritz methods.

UNIT IV NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS (9 hours)
Numerical Solution of Partial Differential Equations - Solution of Laplace's and Poisson equation on a rectangular region by Liebmann's method - Diffusion equation by the explicit and Crank Nicholson implicit methods - Solution of wave equation by explicit scheme.

UNIT V REGRESSION METHODS (9 hours)
Principle of least squares - Correlation - Multiple and Partial correlation - Linear and non-linear regression - Multiple linear regression.
REFERENCES

1. Sankara Rao K., Introduction to Partial Differential Equations, 4th printing, PHI, New Delhi, April 2003

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<th>ME2491</th>
<th>COMPUTER AIDED ENGINEERING GRAPHICS</th>
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PURPOSE

This course is designed to familiarize students with the basics of computer aided engineering graphics and with the possibilities of advanced computer skills for application in solar system design.

INSTRUCTIONAL OBJECTIVES

Upon successful completion of the course the students are able to understand and apply

1. The basics of computer aided engineering graphics.
2. The possibilities of designing and viewing graphic solutions.
3. The tools, features of graphics, techniques and standard graphics software.
4. The modeling techniques using 3-D software.
5. The techniques in designing solar system components.
UNIT I - BASIC CONCEPTS OF ENGINEERING DRAWING (9 hours)
Engineering drawing techniques, dimensions and geometric tolerances, standard viewpoints and section planes, orthographic projections. Points and lines, line drawing algorithms, mid-point circle and ellipse algorithms.

UNIT II - DESIGNING AND VIEWING OF CAE (9 hours)
Filled area primitives - Scan line polygon fill algorithm, boundary fill and flood - Fill algorithms Cramer’s Rule-basic matrix manipulations - Point and normal vector-Line – Vector equation, the intersection of a line with plane.

UNIT III - TOOLS AND FEATURES OF GRAPHICS (9 hours)
3-D geometric transformations - Translation, rotation, scaling, reflection and shear transformations, composite transformations. 3-D viewing coordinates.

UNIT IV - THREE DIMENSIONAL MODELING TECHNIQUES (9 hours)

UNIT V - DESIGN OF SOLAR SYSTEM COMPONENTS (10 hours)
Introduction to engineering design. Basics of project management - Organizing, planning, scheduling and controlling. Application of computer tools - Spreadsheets, project management software, computer aided drafting and design tools.

REFERENCES

51
IK Int. Publ., 2010.

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<th>ME2492</th>
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**PURPOSE**
To familiarize the students with basic concepts of optics and properties of optical materials for solar energy applications.

**INSTRUCTIONAL OBJECTIVES**
Upon successful completion of the course the students are able to understand

1. The basic concepts of optics and optical properties.
2. Phenomena of physical and geometrical optics.
3. The analysis of optics.
4. Concentrator optical analysis.
5. The non-imaging optics and selective solar coatings.

**UNIT I - OPTICAL PROPERTIES** (9 hours)
Basic concepts of physical and geometrical optics. Optical properties of materials, relations between optical properties and band structure.

**UNIT II - OPTICS PHENOMENON** (9 hours)
Phenomena of polarization, photoluminescence, interference, reflection, refraction, transmission, diffraction, dispersion and scattering.

**UNIT III - OPTICS ANALYSIS** (9 hours)
UNIT IV - CONCENTRATION OPTICS (9 hours)
Optics of parabolic cylinders and spheres. Concentration of direct solar radiation by parabolic trough, parabolic dish, heliostat field with central receiver, and Fresnel lenses. Concentration ratio range for each type of concentrators. Reflection of parallel and non-parallel rays. Errors in reflection to a fixed point on a receiver of a solar tower.

UNIT V - NON-IMAGING OPTICS (9 hours)

REFERENCES

ME2496  SEMINAR  
Total Contact Hours-30

Prerequisite
Nil

COURSE DESCRIPTION
Students have to present a minimum of three seminar papers on the topics of current interest and issues. The evaluation will be based on the knowledge of the student on the subject of presentation, their communication abilities, the method of presentation, the way questions were answered and their attention to the other students' seminars.

ME2497  PROJECT WORK – PHASE I

Prerequisite
Nil

COURSE DESCRIPTION
Overview of state-of-the-art solar technology, development and research in the project area. Pre-design of a solar system. Interim report presentation. Students can register for this course only after achieving 12 credits in core courses.

ME2498  PROJECT WORK – PHASE II

Prerequisite
Project – Phase I

COURSE DESCRIPTION
Detailed design of innovative solar thermal, PV and hybrid systems and their components with realistic constraints. Analysis of system performance, economics, and assessment of environmental impact. Final report writing and presentation. Students can enroll for this course only after completing project work phase I.