SRM UNIVERSITY
(Under section 3 of UGC Act 1956)

# 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

| **Type of course** | **Credits to be earned** |
|---|---|
| Core courses | **24** |
| Optional / Elective Courses (Program Electives) | **15** |
| Interdisciplinary elective Course | **3** |
| Supportive courses | **6** |
| Other Courses | **1** |
| Project work Phase I &II | **22 (6+16)** |
| Total | **71** |
| **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**

| Course Code | Course Name | L | T | P | C |
|---|---|---|---|---|---|
| ME2401 | Solar Radiation and Energy Conversion | 3 | 0 | 2 | 4 |
| ME2402 | Heat Transfer in Solar Systems | 3 | 0 | 2 | 4 |
| ME2403 / ME2404 | Control and Drives for Solar Systems (or) Instrumentation and Control in Energy Systems | 3 | 0 | 2 | 4 |
| ME2405 | Solar Collectors | 3 | 2 | 0 | 4 |
| ME2406 | Solar Thermal Systems | 3 | 0 | 2 | 4 |
| ME2407 | Solar Photovoltaic Systems | 3 | 0 | 2 | 4 |

## ELECTIVE COURSES

| Course Code | Course Name | L | T | P | C |
|---|---|---|---|---|---|
| ME2411 | Materials Science for Solar Applications | 3 | 0 | 0 | 3 |
| ME2412 | Design of Solar Energy Systems | 3 | 0 | 0 | 3 |
| ME2413 | Modeling and Analysis of Solar Systems | 3 | 0 | 0 | 3 |
| ME2414 | Structural Analysis in Solar System Design | 3 | 0 | 0 | 3 |
| ME2415 | Nano materials for Solar Applications | 3 | 0 | 0 | 3 |
| ME2416 | Energy Conservation and Management | 3 | 0 | 0 | 3 |
| ME2417 | Energy Efficient Buildings and Systems | 3 | 0 | 0 | 3 |
| ME2418 | Advanced Energy Storage | 3 | 0 | 0 | 3 |
| ME2419 | Research Methodology and Experimental Techniques | 3 | 0 | 0 | 3 |
| ME2420 | Energy Economics and Policy | 3 | 0 | 0 | 3 |
| ME2421 | Conventional and Alternative Energy Systems | 3 | 0 | 0 | 3 |
| ME2422 | Computational Fluid Dynamics | 3 | 0 | 0 | 3 |
| ME2423 | Indian and Global Energy Scenario | 3 | 0 | 0 | 3 |
| ME2424 | Environmental Impact of Energy Systems | 3 | 0 | 0 | 3 |
| ME2425 | Fuel Cell and Hydrogen Technology | 3 | 0 | 0 | 3 |
| ME2426 | Cogeneration and Waste Heat Recovery Systems | 3 | 0 | 0 | 3 |

## SUPPORTIVE COURSES

| Course Code | Course Name | L | T | P | C |
|---|---|---|---|---|---|
| MA2006 / MA2007 | Computational Methods in Engineering (or) Applied Mathematics for Engineers | 3 | 0 | 0 | 3 |
| ME2491 / ME2492 | Computer Aided Engineering Graphics (for students from Science stream) (or) Optics in Solar Energy Applications (for students from Engineering stream) | 1<br>3 | 1<br>0 | 3<br>0 | 3<br>3 |

## OTHER COURSES

| Course code | Course Name | L | T | P | C |
|---|---|---|---|---|---|
| ME2496 | Seminar | 0 | 0 | 1 | 1 |
| ME2497 | Project work Phase I | 0 | 0 | 12 | 6 |
| ME2498 | Project work Phase II | 0 | 0 | 32 | 16 |

| **Mapping of courses** | | | | |
|---|---|---|---|---|
| **Category** | **Number of Courses** | | | |
| | **I semester** | **II semester** | **III semester** | **IV semester** |
| Core courses | 3 | 3 | - | - |
| Optional / Elective Courses | 1 | 1 | 3 | - |
| Supportive courses | 1 | 1 | - | - |
| Interdisciplinary elective course | 1 course of 3 credits to be taken in I or II or III semester | | | |
| Seminar | - | - | 1 | - |
| Project work Phase I | - | - | 1 | - |
| Project work Phase II | - | - | - | 1 |

**CONTACT HOUR/CREDIT:**

**L: Lecture Hours per week** **T: Tutorial Hours per week**

**P: Practical Hours per week** **C: Credit**

## CORE COURSES

| | | L | T | P | C |
|---|---|---|---|---|---|
| ME2401 | **SOLAR RADIATION AND ENERGY CONVERSION** | 3 | 0 | 2 | 4 |
| | **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)**
World energy resources - Indian energy scenario - Environmental aspects of energy utilization. Renewable energy resources and their importance - Global solar resources. Solar spectrum – Electromagnetic spectrum, basic laws of radiation. Physics of the Sun - Energy balance of the Earth, energy flux, solar constant for Earth, green house effect.

**UNIT II - SOLAR RADIATION AND MEASUREMENT (15 hours)**
Solar radiation on the earth surface - Extraterrestrial radiation characteristics, Terrestrial radiation, solar isolation, spectral energy distribution of solar radiation. Depletion of solar radiation - Absorption, scattering. Beam radiation, diffuse and Global radiation. Measurement of solar radiation – Pyranometer, pyrheliometer, Sunshine recorder. Solar time - Local apparent time (LAT), equation of time (E).

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

Solar radiation geometry - Earth-Sun angles – Solar angles. Calculation of angle of incidence - Surface facing due south, horizontal, inclined surface and vertical surface. Solar day length – Sun path diagram – Shadow determination. Estimation of Sunshine hours at different places in India. Calculation of total solar radiation on horizontal and tilted surfaces. Prediction of solar radiation availability.

**UNIT IV - SOLAR THERMAL ENERGY CONVERSION (15 hours)**

Thermodynamic cycles – Carnot – Organic, reheat, regeneration and supercritical Rankine cycles - Brayton cycle – Stirling cycle – Binary cycles – Combined cycles. Solar thermal power plants - Parabolic trough system, distributed collector, hybrid solar-gas power plants, solar pond based electric-power plant, central tower receiver power plant.

**UNIT V - SOLAR ELECTRICAL ENERGY CONVERSION (15 hours)**

Solar photovoltaic energy conversion - Principles - Physics and operation of solar cells. Classification of solar PV systems, Solar cell energy conversion efficiency, I-V characteristics, effect of variation of solar insolation and temperature, losses. Solar PV power plants.

**REFERENCES**


1. Foster R., Ghassemi M., Cota A., "*Solar Energy*", CRC Press, 2010.
2. Duffie J.A., Beckman W.A. "*Solar Engineering of Thermal Processes*", 3rd ed., Wiley, 2006.
3. De Vos, A., "*Thermodynamics of Solar Energy Conversion*", Wiley-VCH, 2008.
4. Garg H.P., Prakash J., "*Solar Energy Fundamentals and Applications*", Tata McGraw-Hill, 2005.
5. Kalogirou S., "*Solar Energy Engineering*", Processes and Systems, Elsevier, 2009.
6. Petela, R., "*Engineering Thermodynamics of Thermal Radiation for Solar Power*", McGraw-Hill Co., 2010.
7. Yogi Goswami D., Frank Kreith, Jan F. Kreider, "*Principles of Solar Engineering*", Second Edition, Taylor & Francis, 2003.
8. Andrews J., Jelley N., "*Energy Science*", Oxford University Press, 2010.

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2402** | **HEAT TRANSFER IN SOLAR SYSTEMS** | **3** | **0** | **2** | **4** |
| | **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)**

Momentum and energy equations, turbulent boundary layer heat transfer – Mixing length concepts, turbulent model – K - ε model. Analogy between heat and momentum transfer – Reynolds, Colburn and Von Karman. High speed flows.

**UNIT III – RADIATION (15 hours)**

Radiation - Gases and vapours. Solar radiation – Sky radiations, solar radiation through fenestrations – Estimations.

**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)**

Finite difference formulation of steady and transient conduction problems. Application of heat transfer in solar thermal system and its components.

**REFERENCE BOOKS**


1. Mills A.F., Ganesan V.," *Heat Transfer"*, 2nd ed., Pearson, 2009.
2. Minkowycz W.J., Sparrow E.M., Murthy J.Y, "*Handbook of Numerical Heat Transfer"*, 2nd ed., Wiley, 2006.
3. Kreith F., Bohn M.S., "*Principles of Heat Transfer"*, 6th ed., Thomson, 2001.
4. Venkateshan S.P., "*Heat Transfer"*, Ane Books Pvt Ltd , New Delhi. 2009.
5. Das S.K., "*Fundamentals of Heat and Mass Transfer"*, Narosa, 2010.
6. Duffie J.A., Beckman W. A. "*Solar Engineering of Thermal Processes"*, 3rd ed., Wiley, 2006.
7. Sachdeva R.C., "*Fundamentals of Heat and Mass Transfer"*, 4th ed., New Age, 2010.
8. Ghoshdastidar P.S., "*Heat Transfer"*, Oxford University Press, 2004.

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2403** | **CONTROL AND DRIVES FOR SOLAR SYSTEMS** | **3** | **0** | **2** | **4** |
| | **Total Contact Hours-75** | | | | |
| | **Prerequisites** | | | | |
| | **Nil** | | | | |

**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**


1. Eduardo F. Camacho, Manuel Berenguel, Francisco R. Rubio, Diego Martinez, "*Control of Solar Energy Systems*", Springer, 2012.
2. Kai Velten., "*Mathematical Modeling and Simulation*", 1st ed., Wiley-VCH, 2009.
3. Johnson C.D., "*Process control and instrumentation*", 8th ed., Pearson, 2006.
4. Palm W.J., "*Introduction to Matlab for Engineers*", 3rd ed., Tata McGraw-Hill Book co, 2010.
5. Meyer W.J., "*Concepts of Mathematical Modeling*", Dover Publ., 2004.
6. Dym C.L., "*Principles of Mathematical Modeling*", 2nd ed., Academic Press, 2004.

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2404** | **INSTRUMENTATION AND CONTROL IN ENERGY SYSTEMS** | **3** | **0** | **2** | **4** |
| | **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 - THRMAL 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)**

Digital Transducers – Interface system and Standards – Computer automated measurements and controls (CAMAC) standards – Remote monitoring and control of boiler houses.

**UNIT V - MICROPROCESSORS (15 hours)**

Microprocessor based temperature control system – Introduction to microcontrollers – Process control system – Pneumatic control systems - Simple circuits.

**REFERENCE BOOKS**


1. Raman, C.S. Sharma, G.R., Mani, V.S.V., *"Instrumentation Devices and Systems"*, Tata McGraw-Hill, New Delhi, 2010.
2. Doeblin, *"Measurement System Application and Design"*, McGraw-Hill, 2010.
3. Morris. A.S, *"Principles of Measurements and Instrumentation"*, Prentice Hall of India, 2009.
4. George C Barney, *"Intelligent Instrumentation Microprocessor and Applications in Measurements and Control"*, Prentice Hall, New Delhi, 2008.
5. Holman, J.P., *"Experimental methods for engineers"*, McGraw-Hill, 2009.
6. Barney, *"Intelligent Instrumentation"*, Prentice Hall of India, 2008.


| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2405** | **SOLAR COLLECTORS** | **3** | **2** | **0** | **4** |
| | **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**


1. Artur V.Kilian., "*Solar Collectors: Energy Conservation, Design and Applications*", Nova Science Publishers Incorporated, 2009.
2. Soteris.A.Kalogiru., "*Solar Energy Engineering: Processes and systems*", 1st edition, Academic press, 2009.
3. K.Sukhatme, Suhas P.Sukhatme., "*Solar energy: Principles of thermal collection and storage*", Tata McGraw Hill publishing Co. Ltd, 8th edition, 2008.
4. Duffie, J. A. & W. A. Beckman., "*Solar Engineering of Thermal Processes*", 3rd edition, John Wiley & Sons, Inc., 2006.
5. H.P.Garg, J.Prakash., "*Solar energy fundamentals and applications*", Tata McGraw Hill publishing Co. Ltd, 2006.
6. D.Yogi Goswami, Frank Kreith, Jan F.Kreider., "*Principle of solar engineering*", 2nd edition, Taylor and Francis, 2nd edition, 2003.
7. G.N.Tiwari., "*Solar energy: Fundamentals, Design, Modeling and Applications*", CRC Press Inc., 2002.


| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2406** | **SOLAR THERMAL SYSTEMS** | **3** | **0** | **2** | **4** |
| | **Total Contact Hours-75** | | | | |
| | **Prerequisites** | | | | |
| | **ME2401 Solar radiation and energy conversion** | | | | |

**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

applications.

5. The fundamentals of design calculations and economics of solar power generation.

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

Thermal comfort - Heat transmission in buildings - Bioclimatic classification. Passive heating concepts - Direct heat gain, indirect heat gain, isolated gain and sunspaces. Passive cooling concepts - Evaporative cooling, radiative cooling, application of wind, water and earth for cooling, roof cooling, earth air-tunnel. Energy efficient landscape design - Concept of solar temperature and its significance, calculation of instantaneous heat gain through building envelope.

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

Flat plate collector – Liquid and air heating - Evacuated tubular collectors - Overall heat loss coefficient, heat capacity effect - Thermal analysis. Design of solar water heating systems, with natural and pump circulation. Solar dryers and applications. Thermal energy storage systems.

**UNIT III - SOLAR COOLING AND DEHUMIDIFICATION (15 hours)**

Solar thermo-mechanical refrigeration system – Carnot refrigeration cycle, solar electric compression air conditioning, simple Rankine cycle air conditioning system. Absorption refrigeration – Thermodynamic analysis – Energy and mass balance of Lithium bromide-water absorption system, Aqua-ammonia absorption system, Calculations of HCOP and second law efficiency. Solar desiccant dehumidification.

**UNIT IV - SOLAR THERMAL APPLICATIONS (15 hours)**

Solar systems for process heat production - Solar cooking – Performance and testing of solar cookers. Seawater desalination – Methods, solar still and performance calculations. Solar pond - Solar greenhouse.

**UNIT V - SOLAR THERMAL POWER PLANTS (15 hours)**

Solar thermal electric power plants based on parabolic trough, solar central receiver, parabolic dish-Stirling engine. Concentrated solar power using Fresnel lenses. Fundamentals of design calculations and analysis of solar power plants. Economic analysis.

**REFERENCE BOOKS**


1. Kalogirou S.A., *"Solar Energy Engineering: Processes and Systems"*, Academic Press, 2009.
2. Vogel W., Kalb H., *"Large-Scale Solar Thermal Power Technologies"*, Wiley-VCH, 2010.
3. Duffie J. A, Beckman W. A., *"Solar Engineering of Thermal Process"*, Wiley, 3rd ed. 2006.
4. Khartchenko N.V., *"Green Power: Eco-Friendly Energy Engineering"*, Tech Books, Delhi, 2004.
5. Goswami D.Y., Kreith F., Kreider J.F., *"Principles of Solar Engineering"*, 2nd ed., Taylor and Francis, 2000, Indian reprint, 2003.
6. Garg H.P., Prakash J., *"Solar Energy Fundamentals and Applications"*, Tata McGraw-Hill, 2005.
7. Laughton C., "So*lar Domestic Water Heating"*, Earthscan, 2010. Yannas S., Erell E., Molina J., Roof Cooling Techniques: Design Handbook, Earthscan, 2006.


| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2407** | **SOLAR PHOTOVOLTAIC SYSTEMS** | **3** | **0** | **2** | **4** |
| | **Total Contact Hours-75** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

**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**

1. Chetan Singh Solanki., *Solar Photovoltaic: "Fundamentals, Technologies and Application"*, PHI Learning Pvt., Ltd., 2009.
2. Jha A.R., "*Solar Cell Technology and Applications*", CRC Press, 2010.
3. John R. Balfour, Michael L. Shaw, Sharlave Jarosek., *"Introduction to Photovoltaics"*, Jones & Bartlett Publishers, Burlington, 2011.
4. Luque A. L. and Andreev V.M., "*Concentrator Photovoltaic*", Springer, 2007.
5. Partain L.D., Fraas L.M., *"Solar Cells and Their Applications"*, $2^{nd}$ ed., Wiley, 2010.
6. S.P. Sukhatme, J.K.Nayak., *"Solar Energy"*, Tata McGraw Hill Education Private Limited, New Delhi, 2010.

## ELECTIVE COURSES

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2411** | **MATERIALS SCIENCE FOR SOLAR APPLICATIONS** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisites** | | | | |
| | **Nil** | | | | |

**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

1. Basics of materials science and engineering.
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**


1. Ramamrutam S., "*Strength of Materials*", $16^{th}$edition, Danpat Rai Publications, 2010.
2. Callister W.D., "*Materials Science and Engineering*", $6^{th}$ edition, Wiley

India, 2009.
3. Sheckel ford J., F. Muralidham M.K., *"Introduction to Materials Science for Engineers"*, 6th edition, Pearson, 2007.
4. RaghavanV., *"Materials Science and Engineering"*, Prentice-Hall India, 2007.
5. Askeland D.R., *"Science and Engineering of Materials"*, 4th edition, Thomson, 2003.
6. Bala subramaniam R., *"Callister's Materials Science and Engineering"*, Wiley India, 2007.

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2412** | **DESIGN OF SOLAR ENERGY SYSTEMS** | **3** | **0** | **0** | **3** |
| | **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**


1. Duffie J.A. and Beckman W.A., *Solar Engineering of Thermal Process*,Wiley,3rd ed., 2006.
2. Da Rosa A.V., *Fundamentals of Renewable Energy Processes*, 2nd ed., Academic Press, 2009.
3. Kalogirou S.A., *Solar Energy Engineering: Processes and Systems*, Academic Press, 2009.
4. Sen Z., *Solar Energy Fundamentals and Modeling Techniques*, Turkey, 2008.
5. Vogel W., Kalb H., *Large- Scale Solar Thermal Power Technologies*, Wiley-VCH, 2010.
6. Dincer I., Rosen M., *Thermal Energy Storage*, 2nd ed., Wiley, 2011.
7. Prasad D., &Snow, M., *Designing with Solar Power*, Earthscan, 2005.

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| **ME2413** | **MODELING AND ANALYSIS OF SOLAR SYSTEMS** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisites** | | | | |
| | **Nil** | | | | |

**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)**

Numerical solution of differential equations - Overview, convergence, accuracy. Methodology of the system modeling, analysis, simulation and economic assessment.

**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**


1. Bender E.A., *"Introduction to Mathematical Modeling"*, Dover Publ., 2000.
2. Meyer W.J., *"Concepts of Mathematical Modeling"*, Dover Publ., 2004.
3. Dym C.L., *"Principles of Mathematical Modeling"*, Elsevier, 2004.
4. Duffie J.A., Beckman W.A. *"Solar Engineering of Thermal Process"*, Wiley, 3rd ed. 2006.
5. Kalogirou S.A., *"Solar Energy Engineering: Processes and Systems"*, Academic Press, 2009.
6. Sen Z., *Solar Energy "Fundamentals and Modeling Techniques"*, Turkey, 2008.
7. Vanek F.M., Albright L.D. *"Energy Systems Engineering"*, McGraw-Hill, 2008.


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| **ME2414** | **STRUCTURAL ANALYSIS IN SOLAR SYSTEM DESIGN** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **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)**

Concepts and principles of strength of materials - Stress and strain, tension, compression, stress-strain diagram. Thermal stresses, principal plane, principal stress, maximum shearing stress. Cylinders and spherical shells.

**UNIT II - PRINCIPLE OF STRUCTURES (9 hours)**

Principles of structural analysis. types of structures and loads, normal force, shear force, bending moment and torsion. Analysis of pin-jointed trusses, cables, arches. Bending, shear, torsion of beams, composite beams, deflection of beams. Complex stress and strain.

**UNIT III - STRUCTURAL ANALYSIS (9 hours)**

Analysis of statically determinate structures. Principle of superposition, determinacy and stability. Analysis of simple diaphragm and shear wall systems, analysis of statically indeterminate structures. Influence lines, structural instability. Approximate analysis of statically indeterminate structures.

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

Vertical and lateral loads on building frames. External work and strain energy. Force method of analysis - Frames, trusses, composite structures. Displacement method of analysis - Beams, frames. moment distribution for beams, frames. Fundamentals of the stiffness method. Matrix analysis of trusses, beams and frames by the direct stiffness method.

**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**


1. Rajan S.D., *"Introduction to Structural Analysis and Design"*, John Wiley and Sons, 2001.
2. Dyrbye C., "*Wind Loads on Structures"*, 3rd edition, John Wiley, 1997.
3. Ramamrutam S., *"Strength of Materials"*, 16th edition, Danpat Rai Publ., 2010.
4. Mc Cormac J.C., *"Structural Analysis: Classical and Matrix Methods"*, 4th ed., Wiley, 2007.
5. Leet K., "*Fundamentals of Structural Analysis"*, 3rd edition., McGraw-Hill, 2008.
6. Al Nageim H., *"Structural Mechanics: Loads", Analysis, Design and Materials,* 7th edition, Prentice Hall, 2010.
7. Hibbeler R.C., *"Structural Analysis"*, 7th edition., Prentice Hall, 2009.


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| **ME2415** | **NANOMATERIALS FOR SOLAR APPLICATIONS** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisites** | | | | |
| | **Nil** | | | | |

**PURPOSE**

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

**INSTRUCTIONALOBJECTIVES**

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 nanomaterials of silicon, silver, gold. General methods of preparation of nanomaterials, thermal and thermo-electric properties of nano structures - modeling and metrology. Nanowires, nanostructures, nanocomposites.

**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)**

Basics of thermal energy storage systems. Application of nanomaterials in solar thermal energy production and storage systems - Sensible, latent heat and chemical energy storages. Nano encapsulated phase change materials in cooling applications. Nanotechnology for electrochemical energy storage.

**UNIT IV - NANOMATERIALS FOR PHOTOVOLTAICS (9 hours)**

Photochemical solar cells, PV panels with nanostructures. Phase compositions on nanoscale microstructures – role of nanostructures and materials – nanomaterials in solar photovoltaic technology- band gap engineering and optical engineering - tandem structures - quantum well and quantum dot solar cells - photo-thermal cells – organic solar cells. Performance and reliability of nanomaterials based solar cells.

**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**


1. Garcia-Martinez.J., *“Nano technology for Energy Challenge”*, Wiley-H Weinheim, 2010.
2. Maheshwar Sharon, Madhuri Sharon, *Carbon “Nano forms and Applications”*, McGraw-Hill, 2010.
3. Tsakalakos.L., *“Nanotechnology for Photovoltaic”s*, CRC, 2010.

4. Wiesner M.R. and Bottero J.Y., *“Environmental Nano technology: Applications and Impacts of nanomaterials”*, Tata McGraw-Hill, 2007.
5. KarkareI.K. , *“Nanotechnology- Fundamentals and Applications”*, IK Intern.Publ.,2008.
6. LeiteE.R., *“Nano structured Materials for Electrochemical Energy Production and Storage”*, Springer, 2009.
7. Eftekhari A., *“Nano structured Materials in Electrochemistry”*, Wiley-VCH, 2008.
8. Allhoff F., *“What is Nanotechnology”*, Wiley, 2010.


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| **ME2416** | **ENERGY CONSERVATION AND MANAGEMENT** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

**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)**

Energy scenario – Principles of energy conservation - Commercial and non-commercial energy, primary energy resources, commercial energy production, final energy consumption. Indian energy scenario, sector-wise energy consumption. Energy needs of growing economy, long term energy scenario, energy pricing, energy security, role of energy managers in industries - Energy audit questionnaire – Energy conservation Acts.

**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)**

Organizational background desired for energy management persuasion, motivation, publicity role, industrial energy management systems. Energy monitoring and targeting - Elements, data, information analysis and techniques – Energy consumption, production, cumulative sum of differences (CUSUM). Energy Management Information Systems (EMIS). Economics of various energy conservation schemes – Energy policy and energy labeling.

**REFERENCES**


1. Reay, D. A., "*Industrial energy conservation*", Pergamon Press, 1st edition, 2003.
2. White, L. C., "*Industrial Energy Management and Utilization*", Hemisphere Publishers, 2002.
3. Beggs,Clive, "*Energy – Management, supply and conservation*", Taylor and Francis, 2ndedition, 2009.
4. Smith, C.B., *Enegy "Management Principles"*, Pergamon Press, 2006.
5. Hamies, "*Energy Auditing and Conservation; Methods, Measurements, Management and Case study*", Hemisphere, 2003.
6. Trivedi, P.R. and Jolka K.R., "*Energy Management*", Common Wealth Publication, 2002.

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| **ME2417** | **ENERGY EFFICIENT BUILDINGS AND SYSTEMS** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

**PURPOSE**
This course provides an introduction to the energy efficient building design, construction, operation and it 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)**
Concepts of energy efficient buildings and energy efficient HVAC systems. Calculation of heating and cooling loads of the building. Building's energy balance accounting for solar energy gain – Heat losses - Internal heat sources. Study of climate and its influence in building design for energy requirement. Low energy and zero energy buildings.

**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)**

Materials, components and details - Insulation – Optical materials – Radiant barriers. Glazing materials – Day lighting – Sources and concepts – Building design Strategies – Case studies – Electric lighting, light distribution, electric lighting control for day lighted buildings and illumination requirement – Components of daylight factor – Recommended daylight factors and day lighting analysis.

**UNIT IV - HEAT CONTROL AND VENTILATION (9 hours)**

Requirements – Heat transmission through building sections – Thermal performance of building sections – Orientation of buildings – Building characteristics for various climates – Thermal design of buildings influence of design parameters – Mechanical controls. Ventilation – Requirements – Minimum standards for ventilation – Ventilation Design – Energy conservation in ventilating systems – Design for natural ventilation.

**UNIT V - GREEN BUILDINGS (9 hours)**

Green building features - Green materials, integrated ecological design, sustainable site and landscaping enhancing ecosystems, indoor environment quality, microclimate, day lighting, water and waste management. Costs and benefits relevance to LEED / IGBC standards - High-performance green buildings - Economics, managing initial costs and environment benefits. International green globes building assessment system.

**REFERENCES**


1. Means R.S., "*Green building: project planning and cost estimating*", Kingston, 2006.
2. Kibert C.J. "*Sustainable Construction: Green Building Design*", 2nd edition, Wiley, 2007.
3. Boecker J., "*Integrative Design Guide to Green Building*", Wiley, 2009.
4. Eicker U., "*Low Energy Cooling for Sustainable Buildings*", Wiley, 2009.
5. Gevorkian P., "*Alternative Energy Systems in Building Design*", McGraw-Hill, 2010.
6. Attmann O., "*Green Architecture*", McGraw-Hill, 2010.

7. Harvey D.L., *"Handbook on Low-Energy Buildings and District-Energy Systems"*, Earthscan, 2006.
8. Majumdar, M., *"Energy – Efficient Buildings in India"*, Tata Energy Research Institute, Ministry of Non Conventional Energy Sources, 2002.

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| **ME2418** | **ADVANCED ENERGY STORAGE** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisites** | | | | |
| | **Nil** | | | | |

**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)**

Modeling of phase change problems – Temperature based model - Enthalpy model - Porous medium approach - Conduction dominated phase change – Convection dominated phase change. Heat transfer with phase change in simple geometries. Basic concepts and modeling of heat storage units - Packed beds.

**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**


1. Ibrahim Dincer and Marc A. Rosen, "*Thermal Energy Storage Systems and Applications*", 2nd Edition, John Wiley and Sons Ltd., 2011.
2. Frank W. Schmidt, A. John Willmott, "*Thermal Energy Storage and Regeneration*", Hemishere Publishing Co., 1981.
3. Charles E. Dorgan, James S. Elleson, "*Design Guide for Cool Thermal Storage*", ASHRAE, Atlanda, 1993.
4. Viskanta R, "*Solar Heat Storage: Latent Heat Materials*", CRC Press, Florida, 1983.
5. G. Beckmann, "*Thermal Energy Storage: Basics, Design, Applications to power generation and heat supply*", Springer, 1984.

6. ASHRAE, *“Handbook of Fundamentals”*, American Society of Heating Refrigeration and Air conditioning Engineers, New York, 1993.

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| **ME2419** | **RESEARCH METHODOLOGY AND EXPERIMENTAL TECHNIQUES** | **3** | **0** | **0** | **3** |
| | **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**


1. Ganesan R, *"Research Methodology for Engineers"*, MJP Publishers, Chennai. 2011
2. Walpole R.A., Myers R.H., Myers S.L. and Ye, King., *"Probability & Statistics for Engineers and Scientists", P*earson Prentice Hall, Pearson Education, Inc. 2007.
3. Anderson B.H., Dursaton, and Poole M.: "*Thesis and assignment writing"*, Wiley Eastern 1997.
4. Bordens K.S. and Abbott, B.b., "*Research Design and Methods"*, Mc Graw Hill, 2008.
5. Graziano, A., M., and Raulin, M.,L., "*Research Methods – A Process of Inquiry"*, Sixth Edition, Pearson, 2007.
6. Leedy., P., D., "*Practical Research – Planning and Design"*, Eighth Edition, Pearson., 2005.
7. Kothari C.K., "*Research Methodology- Methods and Techniques"*, New Age International, New Delhi, 2004.
8. Panneerselvam R., "*Research Methodology"*, PHI Learning, 2012.

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| **ME2420** | **ENERGY ECONOMICS AND POLICY** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

**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)**

Global Energy issues, National and state level energy issues - National and state energy policy, Industrial energy policy, energy security, energy vision. Energy pricing and impact of Global variations. Energy productivity-National and sector wise productivity.

**REFERENCES**


1. Subhes C.Bhattacharyya., "*Energy Economics*", Springer, 2011.
2. Aswathnarayana U., "*Green energy: Technology, Economics and policy*", CRC press, 2010.
3. Russel, C., "*Managing energy from the top Down*", Fairmount press, 2010.
4. Danny Harvey L.D., "*Energy and the New Reality 2: Carbon-free Energy Supply*", Earthscan, 1st edition, 2010.
5. Jacob, "*Energy Policy*", Nova publisher, 2009.
6. Kreith F., Goswami D.Y., "*Energy Management and conservation handbook*", Taylor and Francis, 2007.
7. CIPEC., "*Energy Saving Toolbox*", Natural Resources Canada, 2007.
8. Mallon K., "*Renewable Energy Policy and Politics*", Earthscan, 2006.

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| ME2421 | **CONVENTIONAL AND ALTERNATIVE ENERGY SYSTEMS** | 3 | 0 | 0 | 3 |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

**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 pants, integrated gasification combined cycle, cogeneration plant - Equipment and performance.

**UNIT III - SOLAR AND WIND ENERGY (10 hours)**

Solar radiation – Measurements of solar radiation and sunshine – Solar thermal collectors – Flat plate and concentrating collectors – Solar applications – Fundamentals of photo voltaic conversion – Solar cells – PV applications. Wind data and energy estimation – Wind energy Conversion systems – Wind energy generators and performance.

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

Biomass – Biogas, source, composition - Technology for utilization – Biomass direct combustion, biomass gasifier, biogas plant, digesters, ethanol production, Bio-diesel production and economics. Tidal energy – Wave energy – Technology options – Open and closed OTEC cycles. Geothermal energy sources, power plant and environmental issues.

**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**


1. G.D. Rai, "*Non Conventional Energy Sources*", 4th edition,Khanna Publishers, New Delhi, 2000.
2. S.P. Sukhatme, "*Solar Energy*", Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1997.
3. Godfrey Boyle, "*Renewable Energy, Power for a Sustainable Future*", Oxford University Press, U.K., 2012.
4. Khartchenko N.V., "*Advanced Energy Systems*", Taylor and Francis, Washington DC, 1998.
5. Chauhan D.S., Srivastava S.K. "*Non-Conventional Energy Resources*", New Age, 2009.
6. Georgiadis M.C., "*Energy Systems Engineering*", Wiley-VCH, 2008.
7. Rajput R.K., "*Power Plant Engineering*", 4th ed., Laxmi Publ., 2008.

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| **ME2422** | **COMPUTATIONAL FLUID DYNAMICS** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

**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)**
Governing equations - Laws of conservation- Mass - Momentum - Energy balance and classification, Initial and boundary conditions - Boundary value problems, FEM - Variational formulation - Shape function - Handling B.C in FEM.

**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)**
Solution methods of discretised equations – Tridiagonal matrix algorithm (TDMA) -Application of TDMA for 2D and 3D problems potential flow - Stream and vorticity function. Unsteady flows – Explicit scheme , Crank Nicholson scheme, fully implicit scheme SIMPLE algorithm, PISO algorithm.

**UNIT IV - TURBULENCE MODELING (9 hours)**

Importance ,significance and types - Prantl-mixing length model- One equation model, K-ε model, RSM equation model – Applications.

**UNIT V - GRID GENERATION TECHNIQUE (9 hours)**

Structural grid generation - Algebraic methods, PDE mapping methods. Unstructured grid generation using Delauany – Voronoi methods - Adaptive method - Mesh refinement method - Mesh mover and methods.

**REFERENCES**


1. Zikanov.O., *"Essential computational Fluid Dynamics"*, Wiley 2010.
2. Chung T. J., *"Computational Fluid Dynamics"*, Cambridge University Press, 2003.
3. Hirch .C., *"Numerical Computation of internal and external flows"*, Elesvier 2007
4. Date A.W., *"Computational Fluid Dynamics"*, Cambridge University, 2005.
5. Bates .P.D., *"Computational Fluid dynamics"*, Wiley 2005.
6. Minkowycz. *"Hand book of Numerical heat transfer"*, 2nd Edition Wiley, 2006.
7. Ghoshdastidar. P. S., *"Computer simulation of flow and heat transfer"*, Tata Mc Graw-Hill Publishing company Ltd, 1998.


| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2423** | **INDIAN AND GLOBAL ENERGY SCENARIO** | **3** | **0** | **0** | **3** |
| | **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 – $CO_2$ 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)**

Energy policy issues - Fossil Fuels, renewable energy, power sector reforms, restructuring of energy supply sector, energy strategy for future. Energy conservation act and National electricity policy and plan.

**REFERENCES**

1. Tony Weir, John Twidell., "*Renewable Energy Resources*", 2nd Edition, Taylor And Francis Group , 2005.
2. Jose Goldenberg, Thomas Johansson, A. K. N. Reddy, Robert H Williams., "*Energy for a sustainable world*", 1 Edition June 23, John Wiley & Sons, 1988.
3. Kailash Thakur., "*Environmental protection law and policy in India*", Deep publication private limited, 2007.
4. Susan Baker., "*Sustainable development*" , Routledge, 2006.
5. Mohan Munasinghe and Peter Meier., "*Energy policy modeling and*

*analysis"*, Cambridge university, 1993.
6. Hand book., *"Renewable energy policy and politics"*, Earthscan UK, 2006.

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2424** | **ENVIRONMENTAL IMPACT OF ENERGY SYSTEMS** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

**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 (9 hours)**

Environmental impacts -Environmental degradation due to energy production and utilization.

**UNIT II – POLLUTION (9 hours)**

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 (9 hours)**

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**


1. Khartchenko N.V., "*Green Power: Eco-Friendly Energy Engineering*", Tech Books, and New Delhi, 2008.
2. Cunningham, W.P., "*Environmental Science*", 11th ed., McGraw-Hill, 2010.
3. Venugopal Rao. P., "*Principles of Environmental Science and Engineering*", 2010.
4. Letcher T.M., "*Future Energy*", Elsevier, 2008.
5. Chauhan D.S., Srivastava S.K., "*Non-Conventional Energy Resources*", New Age, 2009.
6. Kruger, P., "*Alternative energy resources*", Wiley, 2008.

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2425** | **FUEL CELL AND HYDROGEN TECHNOLOGY** | **3** | **0** | **0** | **3** |
| | **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)**

Hydrogen production methods. Hydrogen storage - Onboard hydrogen storage - chemical storage - physical storage - in metal and alloy hydrides, carbon nanotubes. Glass capillary arrays - pipeline storage and hydrogen utilization.

**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)**

Cogeneration - Fuel cell electric vehicles - Fuel cell vehicles - Motor cycles and bicycles-airplanes - Fueling stations - Fuel cell power plant structure - Fuel processor and fuel cell stack.

**UNIT V - FUEL CELL RESEARCH (9 hours)**

Power conditioner - Advantages and disadvantages. Problems with fuel cells. Research related to fuel cell development in the world and in India. Energy economy - International agreements on codes, standards and regulations – Policy.

**REFERENCES**


1. Barclay F.J. *"Fuel Cells, Engines and Hydrogen"*, Wiley, 2009.
2. Viswanathan B., *"Fuel Cell Principles and Applications"*, Universities Press, India, 2006.
3. Bagotsky V.S. *"Fuel Cells"*, Wiley, 2009.
4. Larminie J., Dicks A. *"Fuel Cell Systems"*, 2nd ed., Wiley, 2003.
5. Harper G.D.J. *"Fuel Cell Projects for the Evil Genius"*, McGraw-Hill, 2008.
6. Detlef Stolten , *"Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications"*, ,2010.


| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2426** | **COGENERATION AND WASTE HEAT RECOVERY SYSTEMS** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

**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.
4. Waste heat recovery systems, economic analysis and environmental considerations.

**UNIT I - BASIC CONCEPTS OF COGENERATION (9 hours )**

Introduction - Principles of thermodynamics – Cycles - Topping - Bottoming – combined cycle - Organic Rankine cycles – Performance indices of cogeneration systems – Waste heat recovery – Sources and types – Concept of tri-generation.

**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)**

Applications of cogeneration in utility sector – Industrial sector – Building sector – Rural sector – Impacts of cogeneration plants – Fuel, electricity and environment. Environmental consideration – Mitigation of harmful emissions from energy production, conservation and utilization technologies. Control of air, water and ground pollution.

**UNIT IV - WASTE HEAT RECOVERY SYSTEMS (9 hours)**

Selection criteria for waste heat recovery systems – Recuperators, regenerators, economizers, plate heat exchangers, thermic fluid heaters. Waste heat boilers - Classification, location, service conditions, design considerations - Fluidized bed heat exchangers - Heat pipe exchangers - Heat pumps – Sorption systems.

**UNIT V - ECONOMIC ANALYSIS (9 hours )**

Economic concepts - Measures of economic performance – Procedure for economic analysis – Investment cost – Procedure for optimized system selection and design – Load curves - Sensitivity analysis – Regulatory and financial frame work for cogeneration and waste heat recovery systems.

## REFERENCES


1. Khartchenko N.V., "*Green power: Eco – friendly energy engineering*". Tech book, New Delhi, 2004.
2. Boyce M.P., "*Cogeneration and combined cycle plants*", ASME press, 2nd edithion.,2010.
3. Wayce Turner, Steve Doty., "*Energy management handbook*", Fairmont Press, 7th edition, 2009.
4. Charles H.Butler., "*Cogeneration*", McGraw Hill Book Co., 1984.
5. Horlock J.H., "*Cogeneration - Heat and Power, Thermodynamics and Economics*", Oxford, 1987.


## SUPPORTIVE COURSES

| | | L | T | P | C |
|---|---|---|---|---|---|
| **MA2006** | **COMPUTATIONAL METHODS IN ENGINEERING** | **3** | **0** | **0** | **3** |
| | **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**<br>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

**(9 hours)**

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)**

Significance of time series analysis - Components of Time series - Secular trend - Graphical method - Semi-average method - Method of Moving Averages - Method of Least squares - Seasonal variations - Method of Simple Averages - Ratio to trend method - Ratio to moving average method.

**REFERENCES**


1. Sankara Rao K, Introduction to Partial Differential Equations, PHI, New Delhi, 2003
2. Gupta S.C. and Kapoor V.K., Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi, 1999
3. Kapoor V.K., Statistics (Problems and Solutions), Sultan Chand and Sons, New Delhi 1994
4. Montgomery D.C. and Johnson L.A., Forecasting and Time Series, McGraw Hill
5. Anderson O.D., Time Series Analysis: Theory and Practice, I. North-Holland, Amsterdam, 1982.

| | | L | T | P | C |
|---|---|---|---|---|---|
| **MA2007** | **APPLIED MATHEMATICS FOR MECHANICAL ENGINEERS** | **3** | **0** | **0** | **3** |
| | **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**<br>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
2. Elsgolts L., Differential Equations and Calculus of Variations, Mir Publishers, Moscow, 1966
3. S.S. Sastry, Introductory Methods of Numerical Analysis, 3rd Edition, PHI, 2001
4. Gupta S.C. and Kapoor V.K., Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi, Reprint 2003


| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2491** | **COMPUTER AIDED ENGINEERING GRAPHICS** | **1** | **1** | **3** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

## 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)**

Parabolic cylinder differential equation, parabolic cylinder function, parabolic cylindrical coordinates. Helmholtz differential equation. Paraboloid - First and second fundamental forms, Gaussian curvature. Elliptic cylinder, elliptic cone - Doubly ruled surface. Poisson distribution. Use of 3-D solid modeling and CAD software.

**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**


1. Bhattacharyya B., Bera S.C. *"Engineering Graphics"*, IK Int. Publ., 2009.
2. Narayana K.L., Kannaiah P. *"Engineering Graphics"*, 2nd ed., SciTech, 2009.
3. Venugopal K., Prabhu Raja V., *"Engineering Graphics"*, New Age, 2011.
4. Srinivasa Prakash Regalla., *"Computer-Aided Analysis and Design"*,

IK Int. Publ., 2010.
5. Jeyapoovan T., *"Engineering Graphics"*, Vikas Publ., 2010.
6. McMohan C., Browne J., *CAD/CAM "Principles, Practice and Manufacturing Management"*, Pearson, 2000.
7. Khandare S.S., *"Computer Aided Design"*, Charotar Publ., 2001.

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2492** | **OPTICS IN SOLAR ENERGY APPLICATIONS** | **3** | **0** | **0** | **3** |
| | **Total Contact Hours-45** | | | | |
| | **Prerequisite** | | | | |
| | **Nil** | | | | |

**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)**

Intensity at a point due to a plane wave front. Ray analysis. Total internal reflection. Mirror and lens formulae. Electronic inter- bond and intra-bond transitions.

**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)**

Non-imaging optics. Compound parabolic concentrator. Selective coatings for solar collectors.

**REFERENCES**


1. Jha A.K., "*A text book of Applied Physics*", IK International Publishing House Pvt. Ltd., 2009.
2. Chaves J., "*Introduction to Nonimaging Optics*", CRC, Taylor and Francis, 2008.
3. Joseph J. O Gallagher, "*Nonimaging Optics in Solar Energy*", Morgan and Claypool Publishers, 2008.
4. S.K.Dwidedi, "*A text book of Engineering Physics*", IK International Publishing House Pvt. Ltd., 2007.
5. Roland. Winston, Juan C. Minano, Pablo G. Benitez, "*Nonimaging Optics*", Academic Press, 2005.
6. Alan Giambattista, Betty Richardson, Robert C. Richardson , "*College Physics*", 2nd edition, McGraw-Hill Higher Education, 2005.
7. Walker J., "*Fundamentals of Physics*", 3rd edition., Wiley, 2008.
8. Cowell B., "*Optics*", Cowell, 2010 (e-Book).

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2496** | **SEMINAR** | **0** | **0** | **1** | **1** |
| | 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.

| | | L | T | P | C |
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| **ME2497** | **PROJECT WORK – PHASE I** | **0** | **0** | **12** | **6** |
| | **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.

| | | L | T | P | C |
|---|---|---|---|---|---|
| **ME2498** | **PROJECT WORK – PHASE II** | **0** | **0** | **32** | **16** |
| | **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.