PONDICHERRY UNIVERSITY

PONDICHERRY – 605 014

MADANJEET SCHOOL OF GREEN ENERGY ECHNOLOGIES

CENTRE FOR GREEN ENERGY TECHNOLOGY

PhD Program in Green Energy Technology

(To be effective from 2019)

List of Papers for PhD Course Works

PAPER – I : RESEACH METHODOLOGY

Course Code	Title	Mark			Credits
		Internal	External	Total	
GETR751	Research Methodology – Energy Materials and Devices	40	60	100	4
GETR752	Research Methodology – Bioenergy	40	60	100	4
GETR753	Research Methodology – Solar Thermal Energy	40	60	100	4

PAPER – II : RESEACH & ALLIED FIELD

Course Code	Title	Mark			Credits
		Internal	External	Total	
GETR702	Bioenergy and Biophotonics	40	60	100	4
GETR703	Bio-energy & Conversion Systems	40	60	100	4
GETR704	Solar Thermal Energy: Fundamentals, Devices And Systems	40	60	100	4
GETR705	Heat Transfer and Electrical Power	40	60	100	4
GETR706	Nanomaterials: Properties, Synthesis, Characterization and Applications	40	60	100	4
GETR707	Electrochemical Energy Conversion and Storage	40	60	100	4
GETR708	Modeling and Simulation	40	60	100	4
GETR709	Nanotechnology for Energy Systems	40	60	100	4
GETR710	High-temperature Solid State Gas Sensors	40	60	100	4
GETR711	Energy Material Synthesis and Characterization: Nanomaterial, Green material, and hybrid	40	60	100	4
GETR712	Solar Photovoltaic Energy Conversion	40	60	100	4
GETR713	Algal Energy Technology	40	60	100	4
GETR714	Wind Energy & Small Hydropower	40	60	100	4
GETR715	Photovoltaic Device Technology and Applications	40	60	100	4
GETR720	Research Seminar (two seminars on research work to be given prior to submission of synopsis)				-

Instructions:

- Candidates with M.Tech/ M.Phil. are exempted from the course works. If required, Doctoral committee can recommend one paper.
- Doctoral committee will recommend any two papers from the above list or Doctoral committee may recommend one or two papers from other departments/Centres offered at ME/M.Tech/Ph.D level.
- The examination will be conducted by as per the University regulations.
- Passing minimum is 50%.
- Research Seminar is compulsory for all Ph.D scholars.

Eligibility for Ph.D. Admission:

Since research in Green Energy Technology is multidisciplinary in nature, specialized qualification are needed for the admission to Ph.D. in Green Energy Technology. Therefore the Centre shall offer admission to research programme under following thrust areas. The Centre shall call for admission as per the vacancy in any one or more of the thrust areas of research with the defined qualification eligibility criterion indicated therein.

S.No.	Thrust Area of Research	Eligibility for Admission to Ph.D. Programme
1.	Bioenergy and Biofuels	**M.Tech** Biotechnology with minimum 55 % pass OR **M.Tech.** Energy/ Green Energy Technology/ Nanotechnology/ Environmental Engineering with B.Tech in Biotechnology with minimum 55 % pass
2.	Materials for Energy Conversion and Storage	**M.Sc.** Physcis/ Chemistry (with allied Mathematics at BSc level)/ Materials Science with minimum 55 % pass OR **M.Tech**. Energy /Green Energy Technology with B.E./B.Tech in Electrical Engineering/ Electronics with minimum 55 % pass
3.	Solar Thermal Energy Technology	**M.Sc.** Physics with minimum 55 % pass OR **M.Tech** Energy/ Thermal Engineering/ Green Energy Technology with minimum 55 % pass
4.	Solar Photovoltaics	**MSc -**Physics/ Material Science with minimum 55 % pass OR **M.Tech** Material Science/ Nanatechnology /Energy/ Green Energy Technology with **B.E /B.Tech** in Material Science /Electronics Engineering with minimum 55 % pass
5.	Sustainable Development	**M.Tech** Energy/ Green Energy Technology/ Renewable Energy with minimum 55 % pass OR **M.Sc.** Renewable Energy with minimum 55 % pass

PH. D. in Green Energy Technology

Programme Specific Outcome

1. Trained human resource in the area of renewable energy and allied energy technologies
2. Acquire specialization on the chosen field of renewable energy through research and development
3. Gain specific and in-depth understanding on chosen topic of research
4. Acquire general understanding on the fabrication and evaluation of solar cells, battery, supercapacitors and fuel cells, design and installation of PV power plant, solar thermal devices, biodiesel, bioethanol and biogas production
5. Gain knowledge on art of scientific writing, publishing and presenting.

GETR 751 - Research Methodology – Energy Materials and Devices

L T P C
4 0 0 4 60L

Course Objective: To acquire knowledge on research, hypothesizes, research design, conduct of experiment, data collection and analysis – scientific report writing, structure of synopsis and thesis-ethics.

Expected Outcome: Students are expected to understand what research is and how to design and conduct a systematic research, data collection, result analysis, report writing, material synthesis and characterization.

Unit I. Scientific writing and research methodology [12]

Scientific research Aim and motivation – Principles and ethics – identification of research problem – Scientific Methods, Hypotheses Generation and Evaluation – Definition and Objectives of Research – Various Steps in Scientific Research – Usefulness of the research problem –Preparation and presentation of Scientific reports: need and methods – writing of Synopsis and dissertation and thesis. Plagiarism, and Plagiarism checker/software.

Unit II. Data acquisition and analysis [12]

Principle of data acquisition and practice – estimation of errors & confidence level – graphical representation of data. Principle of Matlab and Matlab for data analysis; Principle of Virtual Instrumentation, online and off-line data acquisition and analysis, interfacing of experimental system. Data reduction - Curve fit.

Unit III. Green Energy technology: Research Challenges [12]

Energy flow in major man-made ecosystems- agricultural, industrial and urban ecosystems - sources of pollution from energy technologies and its impact on atmosphere - air, water, soil, and environment Carbon foot printing, carbon sequestration, solar energy production and storage challenges, Carnot efficiency, Shockley-Queisser limit, hydrogen production and storage issues, Thermal energy production and storage issues, bio-energy potential and challenges, estimation of wind energy potential and challenges, concepts in hybrid green energy systems. Energy audit, Energy efficiency.

Unit IV. Materials Synthesis [12]

Top-down and bottom up approaches - Physical methods: Inert gas condensation - Arc discharge-supttering - Laser ablation. Chemical methods: reduction-precipitation – hydrothermal-solvothermal processes - sol-gel, micelle and microemulsions – thermolysis - chemical vapor deposition methods - electrochemical synthesis - synthesis of semiconductors – chemical modification of nanomaterials – functionalization.

Unit V. Advanced Characterization Techniques [12]

Powder XRD and particle size – light scattering and particle size – surface area and porosity – UV and IR studies. Microscopy techniques - Scanning Electron Microscopy (SEM) - Transmission Electron Microscopy (TEM) – Scanning Tunneling Microscopy (STM) - Atomic Force Microscopy (AFM) –

Principle and analysis. Cyclic voltammery, polarization, impedance analysis and equivalent circuit modelling.

Reference Books:

1. Barak, Electrochemical Power sources, I.E.E. series Peter Peregrinus Ltd. Steverage, U.K 1980 reprint 1997.
2. J.O.M. Bockris & A.K.N. Reddy, Modern Electrochemistry, Plenum Press, 1996.
3. E H Thorndike, Energy & Environment: A Primer for Scientists and Engineers, Addison- Wesley Publishing Company
4. R Wilson & W J Jones, Energy, Ecology and the Environment, Academic Press Inc.
5. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.
6. C. S. Solanki, "Solar Photovoltaics: Fundamental Applications and Technologies, Prentice Hall of India, 2009.
7. Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable Comparisons, by Gary C. Young, ISBN:9780470539675, Publisher: John Wiley & Sons, Publication Date: June 2010.
8. Biogas from waste and renewable resources, by Dieter D. And Angelika S. Wiley-Vch Publication 2010.
9. D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press.
10. GL Witte, Philips, S Scbmidt and Daid R Brown, Industrial energy management and utilization, Hemisphere Publishing Corporation, Washington.
11. Carig B, Saith, Energy Management Principles, applications, benefit and saving, Per n Presss, Newyork
12. F W Pyne, P gm Energy Conservation Manual, Fairmount Proem, INC. P.O. Box 14227 Atlanta, GA 30224
13. Instructions to Energy Auditors, Vol. –I & Vol. –II- National Technical Information Services, US Dept. of commerce, Springfield, VA 22161.
14. S.P. Sukhatme, Solar Energy: principles of Thermal Collection and Storage, Tata McGraw-Hill (1984).
15. L.L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
16. Renewable Bioresources - Scope and Modification for Non-Food Applications Edited by Stevens, Christian and Verhe, Roland, Wiley June 2004

GETR 752 - Research Methodology - Bioenergy

L T P C
4 0 0 4 60L

Course Objective: To acquire knowledge on research, hypothesizes, research design, conduct of experiment, data collection and analysis – scientific report writing, structure of synopsis and thesis-ethics.

Expected Outcome: Students are expected to understand what research is and how to design and conduct a systematic research, data collection, result analysis, report writing, material synthesis and characterization.

Unit I. Scientific Writing and Research Methodology [12]

Scientific research Aim and motivation – Principles and ethics – identification of research problem – Scientific Methods, Hypotheses Generation and Evaluation – Definition and Objectives of Research – Various Steps in Scientific Research – Usefulness of the research problem –Preparation and presentation of Scientific reports: need and methods – writing of Synopsis and dissertation and thesis. Plagiarism, and Plagiarism checker/software.

Unit II. Data Acquisition and Analysis [12]

Principle of data acquisition and practice – estimation of errors & confidence level – graphical representation of data. Principle of Matlab and Matlab for data analysis; Principle of Virtual

Instrumentation, online and off-line data acquisition and analysis, interfacing of experimental system. Data reduction - Curve fit.

Unit III. Green Energy Technology: Research Challenges [12]

Energy flow in major man-made ecosystems- agricultural, industrial and urban ecosystems - sources of pollution from energy technologies and its impact on atmosphere - air, water, soil, and environment Carbon foot printing, carbon sequestration, solar energy production and storage challenges, Carnot efficiency, Shockley-Queisser limit, hydrogen production and storage issues, Thermal energy production and storage issues, bio-energy potential and challenges, estimation of wind energy potential and challenges, concepts in hybrid green energy systems. Energy audit, Energy efficiency

Unit IV. Characterization of Biological Materials [12]

Chromatography: Types of column, thin layer, paper, adsorption, partition, gas liquid ion exchange, affinity, HPLC. Electrophoresis- types paper and gel-agarose and PAGE-pulsed field-capillary – isoelectric focusing- blotting methods-western- southern and northern- applications; Spectroscopic characterization: Principles and techniques of colorimetry and Beer-Lamberts Law, Absorption spectroscopy; Spectrofluorimetry -Turbidimetry -DNA, protein and carbohydrate estimation and characterization.

Unit V. Applied Microscopy [12]

Principles of Microscopy: Different types of microscopes, their construction and working principles, Behavior of Light. Light theories Light microscopy- Simple microscopy (dissection microscope), Compound microscopy (Bright field, Dark field, phase contrast, and Fluorescence microscopy), and stereomicroscopy. Confocal microscopy. Electron microscopy, Principles, construction and mode of operation of scanning and Transmission electron microscopy.

References

1. E H Thorndike, Energy & Environment: A Primer for Scientists and Engineers, Addison- Wesley Publishing Company.
2. R Wilson & W J Jones, Energy, Ecology and the Environment, Academic Press Inc.
3. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.
4. C. S. Solanki, “Solar Photovoltaics: Fundamental Applications and Technologies, Prentice Hall of India, 2009.
5. Renewable Bioresources - Scope and Modification for Non-Food Applications Edited by Stevens, Christian and Verhe, Roland, Wiley June 2004
6. Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable Comparisons, by Gary C. Young, ISBN:9780470539675, Publisher: John Wiley & Sons, Publication Date: June 2010.
7. Biogas from waste and renewable resources, by Dieter D. And Angelika S. Wiley-Vch Publication 2010.
8. D. A. Spera, Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press.
9. GL Witte, Philips, S Scbmidt and Daid R Brown, Industrial energy management and utilization, Hemisphere Publishing Corporation, Washington.
10. Carig B, Saith, Energy Management Principles, applications, benefit and saving, Per n Presss, Newyork
11. F W Pyne, P gm Energy Conservation Manual, Fairmount Proem, INC. P.O. Box 14227 Atlanta, GA 30224
12. Instructions to Energy Auditors, Vol. –I & Vol. –II- National Technical Information Services, US Dept of commerce, Springfield, VA 22161.
13. S.P. Sukhatme, Solar Energy: principles of Thermal Collection and Storage, Tata McGraw-Hill (1984).
14. Spectroscopy for Biological Sciences by Gordon G. Hammes, Wiley Interscience, John Wiley & Sons, 2005.
15. Introduction to Biophotonics by P.N.Prasad, Wiley Interscience, John Wiley & Sons, 2003.
16. L.L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.

GETR 753 - Research Methodology – Solar Thermal Energy

L T P C

4 0 0 4 60L

Course Objective: To acquire knowledge on research, hypothesizes, research design, conduct of experiment, data collection and analysis – scientific report writing, structure of synopsis and thesis-ethics.

Expected Outcome: Students are expected to understand what research is and how to design and conduct a systematic research, data collection, result analysis, report writing, solar thermal devices and characterization.

Unit I. Scientific Writing and Research Methodology [12]

Scientific research Aim and motivation – Principles and ethics – identification of research problem – Scientific Methods, Hypotheses Generation and Evaluation – Definition and Objectives of Research – Various Steps in Scientific Research – Usefulness of the research problem –Preparation and presentation of Scientific reports: need and methods – writing of Synopsis and dissertation and thesis. Plagiarism, and Plagiarism checker/software.

Unit II. Data Acquisition and Analysis [12]

Principle of data acquisition and practice – estimation of errors & confidence level – graphical representation of data. Principle of Matlab and Matlab for data analysis; Principle of Virtual Instrumentation, online and off-line data acquisition and analysis, interfacing of experimental system. Data reduction - Curve fit.

Unit III. Green Energy technology: Research Challenges [12]

Energy flow in major man-made ecosystems- agricultural, industrial and urban ecosystems - sources of pollution from energy technologies and its impact on atmosphere - air, water, soil, and environment Carbon foot printing, carbon sequestration, solar energy production and storage challenges, Carnot efficiency, Shockley-Queisser limit, hydrogen production and storage issues, Thermal energy production and storage issues, bio-energy potential and challenges, estimation of wind energy potential and challenges, concepts in hybrid green energy systems. Energy audit, Energy efficiency.

Unit IV. Solar Thermal Energy Conversion Technology [12]

Solar constant; day length; angle of incidence on tilted surface; variation of extraterrestrial radiation; solar radiation at the earth's surface; solar radiation data; sunrise, sunset and day length; local apparent time; Flat plate collectors: Effective energy losses; thermal analysis; heat capacity effect; overall loss coefficient; collector efficiency factor; collector heat removal factor; efficiency of flat plate collectors; testing methods. Evacuated tube collectors: Types; thermal analysis; testing methods. Concentrating collectors: Designing and types; acceptance angle; geometric concentration ratio; optical efficiency; thermal efficiency; testing methods. Selective surfaces.

Unit V. Solar Air Heaters and Thermal Energy Storage [12]

Solar air heater: Materials and components; Natural flow; Forced flow; applications Solar air heating systems: Description and classifications; porous and non-porous type; testing of solar air heater, applications. Solar drying: Working principle; open sun drying; direct solar drying; indirect solar drying; Designing of solar drier; psychrometric chart; energy balance equation.

Reference Books

1. Solar Thermal Engineering Process, Duffle and Beckman, John Wiley & Sons, Fourth edition, 2013.
2. Solar Energy, J.S. Hsieh, Prentice Hall Inc, first edition, 1986.
1. Applied Solar Energy, A.B. Meinel and M.B. Meinel, Addison – Wiley, Second edition, 1977.
2. Solar Thermal Engineering, P.J. Lunde, John Wiley & Sons, First edition,1980.
3. Solar Thermal Energy Storage, H.P. Garg, S.C. Mullick, Vijay K. Bhargava, Springer, 1985.

GETR 702 Bioenergy and Biophotonics

L T P C
4 0 0 4 60L

Course Objective

To impart knowledge on the nature's way of harnessing sunlight by biological systems, enable quest for adopting natural systems and process for specific applications

Course Outcome:

- Learn in detail various microscopic techniques applied to biological research
- Gain knowledge on the state of the art in biological methods to harness sun energy
- Gain knowledge on various bioenergy feedstocks, their energy conversion processes and existing challenges and limitation of the bioenergy sector
- In a position to identify research gaps and possible research direction in bioenergy

Unit I. Instrumental Methods [12]

Principles and techniques of colorimetry and spectrophotometry- - protein estimation methods. Principles of light microscopy – phase contrast & fluorescence imaging - - Confocal Microscopy - Scanning Electron Microscopy (SEM)- Transmission Electron Microscopy (TEM)- Morphological and biochemical characterization of various microbial systems - algae species.

Unit II. Photosynthesis [12]

Chloroplast- structure and function; Photosynthetic pigments and light harvesting complexes, Photo inhibition of photosynthesis, Photosynthetic carbon reduction (PCR) cycle, C4 syndrome and Crassulacean acid metabolism. Oxidative respiration, Alternate electron pathways and Respiration rate. Photosynthesis in algae.

Unit III. Biomass [9]

Biomass: Biomass resources; classification and characteristics; Techniques for biomass assessment; Biomass feedstock in India.

Unit IV. Bioenergy Conversion S ystems: [12]

Biomass to energy conversion systems - direct combustion, incineration, pyrolysis, gasification and liquefaction. Hydrolysis & hydrogenation; solvent extraction of hydrocarbons; solvolysis of wood; biocrude; biodiesel production via chemical process; catalytic distillation; transesterification methods; Fischer-Tropsch diesel: chemicals from biomass.

Unit V. Biodegradation & Microbial Conversion: [10]

Biodegradability of substrate; biochemistry and process parameters of biomethanation; chemical kinetics and modeling of biomethanation process, bioconversion of substrates into alcohol: methanol & ethanol production, organic acids, solvents, amino acids, antibiotics etc.

Reference Books

1. Spectroscopy for Biological Sciences by Gordon G. Hammes, Wiley Interscience, John Wiley & Sons, 2005.
2. Introduction to Biophotonics by P.N.Prasad, Wiley Interscience, John Wiley & Sons, 2003.
3. Lehninger's Principles of Biochemistry by David L. Nelson and Michael M. Cox, Macmillan Worth publisher.
4. Biomass Assessment Handbook - Bioenergy for a sustainable environment Edited by Frank Rosillo-Calle, Sarah Hemstock, Peter de Groot and Jeremy Woods, Earthscan November 2006.
5. Success & Visions for Bioenergy: Thermal processing of biomass for bioenergy, biofuels and bioproducts, Edited by A V Bridgwater, CPL Press September 2007.

GETR 703 Bioenergy and Conversion Systems

L T P C
4 0 0 4 60L

Course Objective

To impart knowledge on the available bioenergy conversion technologies and equip them to identify the state of the art in the field and existing technological gap and challenges.

Course Outcome:

- Learn fundamentals of biochemistry and biological systems for energy application
- Realization of global bioenergy potential, and scenario of bioenergy in India
- Understand various biofuel types and characteristics, limitations and applications
- Understanding of various types of bioenergy conversion systems, principle of working, challenges in exploitation of technology and possibilities of innovations
- Acquire knowledge on algae culture, biomass harvest and biofuel production processes
- Know the national and international biofuel Standards.

Unit I. Biological Systems [14]

Introduction to Biomolecules: Classification of amino acids, carbohydrates and nucleotides; Structure and properties of carbohydrate polymers, proteins and nucleic acids; Classification and utility of lipids and fatty acids; Functional roles of biomolecules – energy carriers, enzyme cofactors and biochemical regulation. Biosynthesis and breakdown of barbohydrates- Lipids- proteins and nucleic acids TCA cycle - Glycolysis - Glyconeogenesis - Pentose phosphate shunt - Urea cycle - Interconnection of Pathways - Metabolic regulations.

Unit II. Biochemical Conversions [12]

Biocatalysis by enzymes and pathways - Fermentation and bioprocess engineering – Chemical kinetics – Mathematical modelling of biochemical reactions – Bioreactor designs; Biodegradation and biodegradability of substrate; anaerobic digestion - Bioconversion of lignocellulosic feedstock to sugars - Bioconversion of sugars and starches to fuels - Difference of the technologies of starch ethanol and cellulosic ethanol.

Unit III. Thermochemical & Chemical Conversions [12]

Thermochemical Conversion: Direct combustion, incineration, pyrolysis, gasification and liquefaction; economics of thermochemical conversion. Biogasification: Biomethanation process, biogas digester types, biogas utilisation; Waste to energy.

Chemical Conversion: Hydrolysis & hydrogenation; solvent extraction of hydrocarbons; solvolysis of wood, biocrude, biodiesel production via chemical process; catalytic distillation; transesterification methods; Fischer-Tropsch diesel: chemicals from biomass.

Unit IV. Algae for Biofuel Application [10]

Introduction to algal biomass; large scale culture and harvest methodologies - Open Raceway ponds & photobioreactors; Biomass and Lipid optimization strategies; Algal biodiesel and bioethanol production process engineering – Concepts of Integrated bioprocess & bio refineries; Social and economic impact of algae as replacement petro fuel.

Unit V. Biofuels Standards & Power Generation [12]

Physical and chemical characteristics of biofuels – Biomass, wood gas, bio methane; ethanol, biodiesel, Wood oil; Bio blends - Indian and International standard specifications. Bio blends; Adaptation of biofuel in various applications – biomass integrated gasification/combined cycles systems - Sustainable co-firing of biomass with coal; Biofuel economy; Biofuel roadmap of India - policy issues, regulatory issues and economic impact; Entrepreneurship in biofuel - Prospects & Challenges, Case studies.

Reference Books

[1] Principles of Biochemistry by David L. Nelson and Michael M. Cox, Macmillan Worth publisher, 2009.
[2] Biochemistry 6th edition by Jeremy M Berg, Lubert Stryer, John L. Tymoczko, 2008.
[3] Voet and Voet’s Biochemistry, D. Voet and J. Voet 3rd Edition, John Wiley and Sons Inc., 2005.
[4] Biochemistry, 5th Ed by Eric E Conn, Paul K Stumpf, George Bruening and Roy H Doi, 2009.
[5] Biofuels - Securing the Planet's Future Energy Needs, Edited by A Demirbas Springer 2009.
[6] Biomass Assessment Handbook - Bioenergy for a sustainable environment Edited by Frank Rosillo-Calle, Sarah Hemstock, Peter de Groot and Jeremy Woods, Earthscan November 2006.
[7] Algal Culturing Techniques, Edited by Robert A. Anderson, Elsevier Academic Press, 2005.
[8] Renewable Bioresources - Scope and Modification for Non-Food Applications Edited by Stevens, Christian and Verhe, Roland, Wiley June 2004

GETR704 Solar Thermal Energy: Fundamentals, Devices and Systems

L T P C
4 0 0 4 60L

Course Objective

The course will generate sufficient knowledge in regards to the working of solar thermal systems and will enable students to design thermal gadgets.

Expected Outcome

- To develop an understanding of basics of solar energy and earth sun relation.
- To develop the ability to use the heat transfer concepts in solar energy and thermal analysis of solar energy devices.
- To analyse the working principle, components, materials used and applications of solar thermal energy gadgets.
- To develop skill for economic analysis of solar thermal engineering projects

Unit I. Solar Radiation Geometry [10]

Solar angles; the earth and solar constant; day length; angle of incidence on tilted surface; variation of extraterrestrial radiation; solar radiation at the earth's surface; solar radiation data; sunrise, sunset and day length; local apparent time; instruments for measuring solar radiation and sunshine; solar radiation on tilted surfaces; analysis of Indian solar radiation data and applications.

Unit II. Solar Collectors: Thermal Analysis [12]

Flat plate collectors: Effective energy losses; thermal analysis; heat capacity effect; overall loss coefficient; collector efficiency factor; collector heat removal factor; efficiency of flat plate collectors; testing methods. Evacuated tube collectors: Types; thermal analysis; testing methods.
Concentrating collectors: Designing and types; acceptance angle; geometric concentration ratio; optical efficiency; thermal efficiency; testing methods. Selective surfaces

Unit III. Solar Thermal Energy Storage [12]

Low, Medium and High temperature thermal energy storage. Sensible heat storage: Types of sensible heat storage; energy analysis in a liquid stratified tank; design aspects; materials for latent heat storage. Latent heat storage: Phase change material (PCM) for latent heat storage; inorganic and organic PCM's; calculation of quantity of material required for latent heat thermal energy storage; design of a solar thermal device with the provision of thermal storage. Thermo-chemical storage: Materials; merits and demerits of thermo-chemical storage; potential of thermo-chemical storage materials for high temperature applications.

Unit IV. Solar thermal energy systems [14]

Solar water heating systems, Solar air heating systems Solar concentrating systems, Solar drying, Solar distillation, Solar pond, Solar cookers, Solar energy for industrial process heat: Hot water, hot air and steam based industrial process heat systems; Solar refrigeration and air conditioning, Solar thermal power generation

Unit V. Economic analysis for solar thermal engineering projects [12]

Annualized cost method: annualized cost; annualized capital cost; salvage value; capital recovery factor; salvage fund factor; annualized maintenance cost; Life cycle savings: savings per day; present worth of annual savings; present worth of cumulative savings. Payback period

Reference Books:

1. Duffle and Beckman, Solar Thermal Engineering Process, John Wiley & Sons, New York
2. J.S. Hsieh, Solar Energy, Prentice Hall Inc. New Jerssey

3. A.B. Meinel and M.B. Meinel, Applied Solar Energy, Addison – Wiley Pub. Co., Reading
4. P.J. Lunde, Solar Thermal Engineering, John Wiley & Sons, New York
5. G.N. Tiwari and S. Suneja, Solar Thermal Engineering Systems, Narosa Publishing House.
6. Renewable Energy Resources, John W Twidell and A D Weir, ELBS
7. Garg H P., Prakash J., Solar Energy: Fundamentals & Applications, Tata McGraw Hill, New Delhi, 1997.
8. J F Kreider and Frank Kreith, Solar Energy Handbook, McGraw Hill.
9. N.C. Harris, C.E. Miller and I.E. Thomas, Solar Energy Systems Design, John Wiley & Sons, New York
10. H.P. Garg, Advanced in Solar Energy Technology, D. Reidel Publishing Co., Drdricht.
11. S.P. Sukhatme, Solar Energy, Tata McGrew Hill Company Ltd., New Delhi
12. F. Kreith and J.F. Kreider, Principles of Solar Engineering, Hemisphere Publishing Coro.

GETR705 Heat Transfer and Electrical Power

L T P C
4 0 0 4 60L

Course Outcome:

- Learn various modes of heat and mass transfer analysis of applied to different thermal systems.
- Learn in detail generation, transmission and distribution aspects of electric power.
- Carry out cost analysis of electrical power and comprehend parameters associated with electric power generation and load management.

Unit I. [12]

Laws of Thermodynamics, Sterling Engine: Principle, working and efficiency Basic Heat Transfer Concept and Terminology: Basic concepts terminology; Heat transfer coefficients; Thermal resistance; Overall heat transfer coefficient.
Conduction: Conduction equation; Steady state conduction in simple geometries; Thermal contact Resistance; Critical thickness of insulation; Multidimensional steady state heat conduction (Shaper Factor); Extended surfaces; Types of fins; Effectiveness and efficiencies of fins; Transient heat conduction; Lumped heat capacity analysis; Heiler's charts for semi-Infinite medium; Slab cylinder and sphere; Periodic heat conductions.

Unit II. Convection [12]

Principle of similarity; Mechanism of convection; Concept of velocity boundary layer; Concept of thermal boundary layer; Evaluation of dimensionless parameters; Forced flow convection (Laminar, Turbulent &Mixed); Boundary layer thickness; Convective heat transfer coefficient; Drag coefficient for flat plate, Inside tube , cylinder, sphere and banks of tubes, Free convection (Laminar, Turbulent Mixed) on horizontal, vertical and Inclined plates, cylinder and sphere; forced convection inside tubes and ducts; Forced convection over exterior surfaces.

Unit III. Radiation [12]

Blackbody radiation; View factor algebra; Enclosures with black surfaces and grey surfaces; Radiosity; Heat exchangers and its types; Effectiveness, LMTD and NTU methods.

Unit IV. Electrical System [12]

Introduction to electric power supply systems: Power generation plant, Transmission and distribution lines, Cascade efficiency; Electrical billing; Electrical load management and maximum demand control; Power factor improvement and benefits; Transformers; Distribution losses in industrial system; Assessment of Transmission and Distribution (T&D) losses in power systems; Estimation of technical losses in distribution system; Demand side management; Harmonics.

Unit V. Material and Energy Balance [12]

Energy intensity on purchasing power parity (PPP); Energy pricing in India; Energy units and conversation; Purpose of material and energy balance; Components of material and Energy balance; Basic principles of material and energy balance; Classification of processes: steady- state process, unsteady state process; Material balance: levels of material balance; Material balance procedure; Energy balance; Efficiency and losses; Facility as an energy system; Energy balance in power plant cycle; Energy analysis; Energy action planning.

References

1. M.N. Oziesik, Heat Transfer - A Basic Approach, McGrew Hill Book Co., New Delhi.
2. M.Becter, Heat Transfer: A Modem Approach
3. S.P. Shukatme, Heat Transfer, Orient Longman, New Delhi.
4. W.H. Giedt, Principles of Engineering Heat Transfer, D.Van Norstand Company Inc. (1961)
5. T. Gonen, Electric Power Distribution System Engineering, McGraw Hill Book Co. (1988)
6. Process Integration, Chapter of Energy Efficiency, By Eastop. Bejan Adrian – Heat Transfer
7. Y. Bayazitoglu – Element of Heat Transfer Karlekar – Heat Transfer J.P. Holman – Heat Transfer Robin Smith – Chemical Process (Design and Integration)

GETR 706 Nanomaterials: Properties, Synthesis & Characterization and Applications

L T P C
4 0 0 4 60L

Course Outcome:

- Develop computational skill for the study of nanomaterial properties
- Lean various methodologies for the synthesis of nanomaterial
- Lean theory and practice of various nanomaterial characterization techniques

Unit I. Properties at Nanoscale [12]

Comparison of properties at bulk and nano - Nanomaterials – nanostructures, chemical and physical properties-surface-to-volume ratio, density of states - Quantum confinement and Bohr exciton radius - Quantum size effects, electrical, optical & magnetic properties. Origin of Surface plasmon resonance in metallic nanoparticles – Absorption and emission properties of semiconductor nanocrystals.Carbon-based nanomaterials.

Unit II. Nanomaterials by Physical and Chemical Methods [12]

Top-down and bottom up approaches - Physical methods: Inert gas condensation - Arc discharge-sputtering - Laser ablation. Chemical methods: reduction-precipitation – hydrothermal-solvothermal processes - sol-gel, micelle and micro emulsions – thermolysis - chemical vapor deposition methods - electrochemical synthesis - chemical modification of nanomaterials – functionalization.

Unit III. Green Synthesis of Nanomaterials [12]

General approach for green synthesis – principles - Green synthesis of metals and alloys – use of natural resources and biosynthesis of nanomaterials. Microwave synthesis of nanomaterials.

Unit IV. Structural and Morphological Characterization [12]

Powder XRD and crystallite size–light scattering and particle size – surface area and porosity – UV and IR studies.Microscopy techniques - Scanning Electron Microscopy (SEM) - Transmission Electron Microscopy (TEM) – Scanning Tunnelling Microscopy (STM) - Atomic Force Microscopy (AFM) – Principle and analysis.

Unit V. Applications of Nanomaterials and Societal Implications [12]

Nanomateirals and Nanotechnology General applications – green technology and green energy applications - Industrial manufacturing, materials and products, medicine and clean environment - implications for philosophy, ethics and society.

Reference Books

1. Guozhong Cao, Nanostructures and Nanomaterials, Imperial College Press, 2004, London.
2. Charles P. Poole, Frank J. Owens, Introduction to Nanotechnology, A John Wiley & Sons, inc.
3. Pradeep T., Nano:The Essentials: Understanding Nanoscience and Nanotecnology, Tata McGraw-Hill Publishing Company Limited, New Delhi,2008.
4. Rao C.N.R, Müller, Cheetham, The Chemistry of Nanomaterials, Vol 1 and 2, Wiley-VCH VerlagGmBH& Co., Weinheim, 2004.
5. Nanotechnology: assessment and perspectives, H. Brune et al., New York, Springer, 2006.
6. Nano-hype: the truth behind the nanotechnology buzz, David M. Berube; Amherst, N.Y., Prometheus Books, 2006.
7. Edelstin A.S. and CammarataR.C..Nanomaterials: Synthesis, Properties and applications, Institute of Physics Publishing 1996.
8. M.C. Roco and W.S Bainbridge, Nanotechnology: Societal Implications II – individual Perspectives, Springer publishers, sponsored by National Science Foundation, Netherlands, 2003

GETR707 Electrochemical Energy Conversion and Storage

L T P C
4 0 0 4 60L

Course Outcome:

- Enrich knowledge on state of the art in energy conversion & storage
- Gain know-how on battery and fuel cell functioning
- Gain knowledge on various fabrication technology of battery and fuel cells
- Get insight into existing issues and challenges in energy storage, particularly of renewable energies using battery

Unit I. Introduction [12]

Electrochemical cell, electro motive force, free energy changes and emf, concentration of the reactants on EMF, effect of cell temperature, derivation of number of electrons involved in a cell reactions, thermodynamic calculations, electrochemical series-equilibrium potential, Nernst equation- Battery types – primary and secondary batteries and examples - theoretical voltage, capacity, energy & specific energy, power & specific power.

Unit II. Primary Batteries [12]

Dry cells-zinc/carbon battery, alkaline primary batteries, Zn/air, Lithium batteries, reserve batteries: principle, components, construction, characteristics, applications, and problems associated with the systems.

Unit III. Secondary Batteries [12]

Principle, construction, components, merits and demerits of lead acid, nickel-cadmium, nickel- metal hydride, lithium-ion batteries-Possible applications.

Unit IV. Supercapacitors [12]

Introduction to supercapacitors, types of supercapacitors, reagone plot, similarities and differences between supercapacitors and batteries, electrode interface & double layer capacitors- redox capacitors-construction and performance evaluation, materials for supercapacitors and technology development – typical examples.

Unit V. Fuel Cells [12]

Introduction to fuel cells, merits and demerits, comparison to batteries & internal engines, types of fuel cells, EMF of fuel cells, Nernst equation, efficiency, current versus potential issues, fuel cell reaction kinetics, ORR, MOR, selection of fuel, electrode, electrolyte and membranes-fuel cell charge transport, fuel cell mass transport, fuel cell characterization, fuel cell losses, hydrogen - oxygen fuel cell, PEMFCs, DMFCs, PAFCs, molten carbonatate fuel cells, SOFCs and Biofuel cells.

Reference Books

1. Barak, Electrochemical Power sources, I.E.E. series Peter Peregrinus Ltd. Steverage, U.K 1980 reprint 1997.
2. J.O.M. Bockris & A.K.N. Reddy, Modern Electrochemistry, Plenum Press, 1996.
3. A.J. Bard & L.R. Faulkner, Electrochemical Methods Fundamentals and Applications, John Wiley Sons. 2nd Edition, 2001.
4. B.E. Conway, Electrochemical supercapacitors: scientific fundamentals and technological applications, Kluwer Academic / Plenum publishers, New York, 1999.
5. T.R. Crompton, Batteries reference book, Newners, 3rd Edition, 2002.

GETR708 Modelling and Simulations

L T P C
4 0 0 4 60L

Course Outcome:

- Mathematical understanding of green energy systems
- Numerical calculations with advanced scientific software

- Programming skill development in research and engineering software
- Developing skill to identify the problem related to green energy system and design a solution through modelling and simulation.

Unit I. [9]

Introduction to mathematical modelling: - Physical and mathematical models, Good programming, debugging and testing, Numerical integration –Differentiation, Elementary computer graphics.

Unit II. [10]

Fundamentals of Programming: Introduction to computational softwares: Programming in computational software (wih the help of a specific software eg. MatLab, Mathematica, Femlab etc)- Multidimensional Arrays Polynomial Operations Using Arrays- Mathematical Functions User Defined Functions- Advanced Function Programming- Working with Data Files Program Design and Development- Graphics plotting functions Special Plot types Interactive plotting- Function Discovery Regression, 3-D plots, GUI-design.

Unit III. [14]

Graphical Programming: Starting graphical programming (with the help of any one of graphical programming software, eg: Simulink, Femlab etc) t. Model Files, Basic Elements-: blocks and lines.- Running Simulation-Building Systems- Block Libraries.: Sources, Sinks, Discrete, Linear. Nonlinear, Connections- - Interaction With other programmes (eg: Simulink with MatLab)- Defining Block Parameters Using Matlab, Variables-Exchanging Signals With other programmes Extracting Models (eg:Simulink into Matalb).

Unit IV. [15]

Lab exercises to develop simple Scripts and models related to building energy systems involving applications of data analysis, optimization, advanced graphics, diode model and simulation, simple photovoltaic models and simulation, DSSC model and simulation, FPC optimization model. Nanosystems model.

Unit V. [12]

Hybrid system modelling, PVT model, Wind Turbine/generator: Modelling of PV Solar Array: Simulation of power output of PV systems, Modelling of PEM Fuel Cell.

Reference books:

1. Modelling and Simulation: Exploring Dynamic System Behaviour, by Louis G. Birta, ISBN:9781846286216, Publisher: Springer, 2007
2. An Engineer's Guide to MATLAB: With Applications from Mechanical, Aerospace, Electrical, and Civil
3. Engineering E. B. Magrab S. Azarm B. Balachandran J. H. DuncanbK. E. Herold G. C. Walsh Prentice Hall 2004 PEM Fuel Cell Modeling and Simulation Using MATLAB by Colleen Spiegel, Academic Press 2007
4. Energy Simulation in Building Design, J A Clarke, 2002 (2nd Edn)
5. G.M.Masters, Renewable and Efficient Electric Power Systems, Wiley 2004.

GETR709: Nanotechnology for Energy Systems

L T P C
4 0 0 4 60L

Course Outcome:

- Learn in detail nanomaterial's basics, synthesis, characterization and broad application.
- Will be in a position to assess societal impact of nanomaterial
- Learn necessary methodologies in adopting various nanomaterial for device application
- Shall be in a position to appreciate merits and demerits of nanomaterial for specific application

Unit I. Nano-electronics [12]

Atom by Atom arrangements , band structure formation, concept of wave, phase group velocities, electron state in solids, uncertainty principle, operators, wave properties of particle, quantum mechanical postulates, Schrödinger's Wave Equation, free electron gas, spherical potential (hydrogen atom like problem), Hydrogen molecule like problem , electronic states of 2- D, 1-D, 0-D nanosystems.

Unit II. Physical Properties of Nanosystems [12]

Absorption, refraction, self electro optic effect, QCSE and Pockel effect in nanosystem, transport properties of nanosystems, partition function and thermodynamics of nanosystems.

Unit III. Nanotechnology for Photovoltaic Energy Conversion [12]

Challenges in energy conversion – role of nanostructures & materials – nanomaterials in solar Photovoltaic Technology: Bandgap engineering & optical engineering - Tandem structures - quantum well and quantum dot solar cells - Organic solar cells.

Unit IV. Nanotechnology for Photoelectrochemical & Photothermal Conversion Cells [12]

Concept of photo-electro chemical cell. Conversion of solar energy to hydrogen, technology for storage, photo-thermal cells, nanotechnology in thermal conversion, nanosystems for heat storage.

Unit V. Energy Efficient Nanodevices [12]

Energy efficient devices –fabrication and applications of LED as light device – OLED – Semiconductor laser – single electron & single photon devices – energy efficient switches &modulator, amplifiers and lasers – MEMS & NEMS and their energy efficiency

Reference Books

1. Physical principles of micro Micro-electronics, G.Yepifanov, Mir Publishers
2. Semiconductor device-basic principles-Jasprit singh, Wiley
3. Quantum Chemistry, Levine, Prentice Hall
4. Statistical Mechanics and properties of matter, E.S.R Gopal,Ellis Horwood
5. Introduction to solids, Azaroff, Tat Mc-Graw Hill

GETR710: High Temperature Solid State Gas Sensors

L T P C
4 0 0 4 60L

Course Outcome:

- Learn various technological approach in fabrication and characterization of sensor materials
- Develop skill to relate the choice of materials to the specific application for device fabrication

Unit-I Introduction [12]

Environmental air pollution – sources – effect on environment and eco-system – automobile emissions – emission norms – US, Europe and Indian norms – Three Way Catalysts –NO_x storage catalyst-$DeNO_x$ system – in cylinder and post cylinder Technologies-Selective Catalytic Reduction.

Unit-II Solid State Sensors [12]

Solid State Sensors –types – principles – sensor configuration – high temperature sensors – electrochemical sensors: potentiometric – amperometric – impedancemetric. Sensitivity – selectivity – response/recovery rates and stability. FET and MOSFET and their applications.

Unit-III Fabrication [12]

Solid electrolytes–zirconia, perovskite, other oxide-ion conductors – YSZ- fabrication methods – hand pasting – transfer print technique – sputtering – laser sputtering – sensor types – planar, parallel planar and tubular types. Reference electrodes – sensing electrodes-current collectors– binders– sintering processes.

Unit-IV Sensing modes [12]

Mixed-potential-type, amperometric, impedancemetricsensors –special features – literatures - progress, issues and challenges.

Unit-V Applications [12]

Applications in environmental monitoring – indoor & outdoor air quality monitoring –agricultural fields - traffic signals. High temperature applications: Industrial furnaces and Automobiles- specific examples-commercial sensors available.

Reference Books

1. Solid State Gas Sensing, Eds.: ElisabettaComini, Guido Faglia, Giorgio Sberveglieri, Springer, 2008.
2. Theodor Doll, Advanced Gas Sensing: The Electroadsorptive Effect and Related Techniques, Springer, 2003.
3. C. O. Park*et al.*, Solid-state electrochemical gas sensors, *Ionics***15** (2009), 261.
4. T. Wagner*et al*., Mesoporous materials as gas sensors, *Chem. Soc. Rev***42** (2013),4036.
5. F. H. Garzon*et al*., Solid-state mixed potential gas sensors: theory experiments andchallenges*Solid State onics***136–137**(2000), 633.
6. Jeffrey W. Fergus, Sensing mechanism of non-equilibrium solid-electrolyte-based chemical sensors, *J Solid State Electrochem***15** (2011), 971.
7. Other related journals

GETR711 Energy Materials Synthesis and Characterization: Nanomaterials, Polymer and composite materials

L T P C
4 0 0 4 60L

Course Outcome:

- Acquire understanding on the basics of polymers and composites synthesis, analysis, and testing its properties.
- Develop ability to synthesis various types of polymeric and composite materials for specific applications such as solar PV, solar thermal, wind turbines, batteries, fuel cells, and related renewable energy technologies.
- Acquire state of the art in polymeric and hybrid composite materials in the field of renewable energy.

Unit I. Green Synthesis of Nanomaterials: [10]

Nanomaterial basics, synthesis, Top-down and bottom up approaches - Physical and Chemical methods, General approaches for green synthesis – principles - Green synthesis of metals and alloys – use of natural resources and biosynthesis of nanomaterials.

Unit II. Fundamentals of Polymers and Composites [10]

Basics, classification, structures, nomenclature, polymer synthesis, properties– polymer length, molecular weight, amorphous and crystalline. Organic semiconductors- conjugated polymers, charge transport in organic semiconductors. Introduction to composites-polymer matrix, polymer membranes, and carbon nanocomposites- types, preparation and properties of composites.

Unit III. Polymers and Composites for Solar Energy [12]

Organic photovoltaics: Introduction- principles of organic, polymer and hybrid photovoltaics. Bulk hetero-junction devices based on organic/polymeric materials. Organic versus inorganic solar cells. Organic photoactive material synthesis- low bandgap conducting polymers. Processing, printed plastic and stability of organic polymer and metal oxide–polymer solar cells. Polymers and composites as solar thermal materials for solar thermal -polymeric solar absorbers and polymer solar reflector.

Unit IV. Polymers and Composites for Wind and Biomass Energy [14]

Composite material synthesis - glass, carbon, resins, aramid fibre-reinforced polymeric composites, natural fiber reinforced polymers- biocomposites, and nanocomposites for wind turbine blades. Composite manufacturing and testings for blades. Composites catalysis in biochemical/thermochemical biomass conversion to biofuels: hydrolysis, hydrotreating, reforming, liquefaction, gasification, pyrolysis, Fischer–Tropsch synthesis, transesterification and others.

Unit V. Polymers and Composites for Fuel Cells, Batteries and MFCs [14]

Polymer electrolyte membrane synthesis and characterization: Structure–property relationships, and membrane electrodes for fuel cells, microbial fuel cells and batteries. Design and development of ion exchange membranes fuel cell for energy conversion - Nafion, sulfonated PBI, sulfonated poly(ether-

ether ketone)s and sulfonated poly(aryl ether). Polymer composite membrane - role of cation, aninon, proton-exchange membranes in bioelectrochemical systems (MFCs) –construction and performance of MFCs.

References

1. Bill Meyer, A Text Book of Polymer Chemistry, John Wiley & Sons, 1994
2. Gowariker and Viswanathan, Polymer Science, Wiley Eastern, 1986.
3. S.L. Kakani and Amit Kakani, Material Science, New Age Int. Publisher, 2004
4. Deborah and D.L.Chung Composite Materials, Springer publication, 2002.
5. Tony Burton, Nick Jenkins, David Sharpe, and Ervin Bossanyi, Wind energy –Hand book (2^{nd} Edition), John Wiley & Sons, 2011
6. Nigel Sammes, Fuel cells- Hand book, Seventh Edition, 2004
7. Frano Barbir, PEM fuel cells- theory and practice, Elsevier Publication, 2005.
8. Nanostructured Conductive Polymers, Editor. Ali Eftekhari, Wiley, 2010.
9. Organic Photovoltaics, CRC press-Taylor & Francis, Edited by Sam-Shajing Sun, Niyazi Serdar Sariciftci, 2005.
10. WOLEDs and organic Photovoltaics, Springer, Edited by Vivian W. W. Yam, 2010.
11. New and future development in catalysis, Elsevier Publication, edited by Steven L. Suib, 2013.
12. Catalytic for renewables, Wiley-VCH Verlag GmbH & Co. KGaA, Edited by Gabriele Centi and Rutger A. van Santen 2007.
13. PEM fuel cells- Material properties and performance, CRC press-Taylor & Francis, Editors: Hui Li, Shanna Knights, Zheng Shi, John W. Van Zee, Jiujun Zhang, 2010.

GETR712 Solar Photovoltaic Energy Conversion

L T P C
4 0 0 4 60L

Course Objective: This course highlights about the solar energy, solar energy conversion principles, fundamentals about semiconductors and their application for solar cell fabrication and solar characterization

Expected Outcome: Students will have complete understanding about the solar energy and their conversion principles – solar cell fundamentals – solar cell fabrication and characterization techniques.

Unit-I Solar Energy [10]

Solar energy availability: space and terrestrial availability – Solar Energy measurements: direct, diffused and global radiations - Solar energy conversion principles and technologies – optical **pyrheliometer &** optical pyranometer – solar simulators – solar concentrators

Unit – II Semiconductor [1 2]

Semiconductors: atomic bonding, crystals structures, energy band diagram, direct & indirect bandgap semiconductors – Intrinsic & extrinsic semiconductor, carrier doping and carrier concentration – carrier doping and band structures - Electrical resistivity and Hall effect measurements - compound semiconductors - diffusion and drift of carriers, continuity equation - optical absorption - carrier recombination -Effect of external parameters : pressure, electrical & magnetic fields and temperature.

Unit-III Semiconductors for Solar Cell [12]

Silicon: preparation of metallurgical, electronic and solar grade Silicon - production of single crystals : Czokralski (CZ) and Float Zone (FZ) growth, imperfections - carrier doping and lifetime - wafer production, Germanium : production, crystal growth, doping and wafer production - compound semiconductors: III-V, II-VI and other types applicable for solar cell fabrications, growth & characterization - amorphous semiconductors - organic semiconductors -Transparent conducting oxides - anti-reflection principles and coatings

Unit-III Photovoltaic Device Fabrication [14]

Semiconductor junctions: Schottky barriers, MIS, P-N junction, p-i-n junction and its properties Homo & hetero junction solar cells, multijunction solar cells- Fabrication techniques: Diffusion, thin film technology- physical vapour deposition (PVD)- Electro-deposition-Molecular beam epitaxy (MBE)- Metal organic chemical vapour deposition (MOCVD)- Plasma enhanced chemical vapour deposition (PECVD)- Organic and Nano tech solar cells – contact & grid metallization: photolithography - thermo photovoltaic devices and fabrication procedures- space quality solar cells

Unit-IV Device Characterization and Analysis [12]

Device isolation techniques - Ideal cell under illumination- solar cell parameters short circuit current, open circuit voltage, fill factor, efficiency; optical losses; electrical losses, surface recombination velocity, quantum efficiency - measurements of solar cell parameters; I-V curve & L-I-V characteristics, Quantum yield measurements – Effects of temperature, series, parallel resistance - Loss analysis.

References

1. Solar Cells and their Applications, Larry D Partain (ed.), John Wiley and Sons, Inc, New York, 1995.
2. J. Nelson, The physics of solar cells, Imperial College Press, 2006.
3. Photovoltaic Materials, Richard H Bube, Imperial College Press, 1998
4. Practical Photovoltaics: Electricity from Solar Cells, by Richard Komp, Aatec Publications, 2002.
5. Fundamentals of Photovoltaic Modules & Their Applications by G.N.Tiwari, Publisher: Royal Society of Chemistry, 2010.
6. Solar Cells: Operating principles, Technology and Systems Applications, Martin Green, UNSW, Australia, 1997.

GETR713: Algal Energy Technology

L T P C
4 0 0 4 60L

Course Outcome:

- Able to assess the energy potential of various algal species and their culturing techniques
- Develop basic understanding of growth, characterization and lipid extraction for biofuel production Learn methodologies and instrumentation required for large scale algal biomass production
- Will become familiar with various standards of biodiesel and bioethanol.

Unit I. [10]

Biomass to Energy – Types of biomass feedstocks. Macroalgae and seaweeds – Classification of carbohydrate rich and lipid rich algae – Algae biomass for briquetting – Algal biomass for energy food application – Characterization of bio-oil in algal strains.

Unit II. [12]

Taxonomic variation of algae - sampling, culture and biomass estimation – Algae as bioindicators. Macroalgae and microalgae – characteristics of microalgae for biofuel application. Systems view of algal metabolic network – biomass and lipid optimization in algae – stress control and genetic engineering approaches. Characterization of photosystems in microalgae – energy conversion efficiencies - optical characteristics of photoactive proteins in algae – recent development in artificial leaves and biosolar cells

Unit III. **[**12]

Cultivation of Algae for biodiesel and high value chemicals: Laboratory culture, Open raceways ponds, closed photobioreactors, design and illumination concepts - continuous culture and biomass recovery – light stress and its quantification – optimization of biomass and lipid.

Unit IV. **[**12]

Chemical synthesis of biodiesel: Liquefaction of algal cells by hexane extraction - catalytic distillation - transesterification - Fischer-Tropsch diesel. Large scale biomass production and lipid yield optimization – Recent development in algal culture technology. Biocrude from algae – biorefinery for fuel production.

Unit V. **[**14]

Conventional fuels versus biofuels – methods of physical characterization of algae biodiesel - ASTM standard for fuel and biofuel blends – enhancement of biofuel properties – challenges and limitation in the use of biofuel – socio-economic aspects of algae as alternate fuel – algal technology in Indian scenario and Global trend.

Reference Books:

1. Freshwater Algae: Identification and Use as Bioindicators by Edward G. Bellinger and David C. Sigee, Wiley-Blackwell, John Wiley & Sons, 2010.
2. Resource Manual & Technical Manual, edited by S.Seshandri et al. A Bioresource Document compilation by Shri MurugappaChettiyar Research Centre, Sponsored by National Bioresoruce Development Board, DBT, India.
3. Biodiesel Handling and Use Guide, Fourth Edition, an online document by National Renewable Energy Laboratory, USA. http://www.osti.gov/bridge
4. Algae by Linda E. Graham and Lee W. Wilcox, Prentice Hall, 2000.

GETR714 Wind Energy & Small Hydropower Systems

L T P C
4 0 0 4 60L

Course Outcome:

Student will learn to assess the wind energy potential of a place, understand the various component of wind energy conversion system, get introduced to design and engineering aspects of wind turbine and control systems. Familiarize with different type of wind electric power generators. Lean basics of costing wind power generation. Also get know basics of small hydropower plant classification, installation detail and its impact on clean energy generation.

Unit I. Wind Energy Potential [10]

Wind Velocity Distribution – Estimation of wind resource – Wind Indian and Global scenario.

Unit II. Wind Energy Conversion [12]

Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and Strip theory; Maximum power coefficient; Prandlt's tip loss correction; Rotor design and characteristics; Power, torque and speed characteristics – Wind turbine performance measurement – Loading analysis.

Unit III. WECS design considerations [12]

Design of WECS components – Stall, pitch & yaw control mechanisms – Brake control mechanisms; Theoretical simulation of wind turbine characteristics; Test methods.

Unit IV. Wind Energy Application [12]

Wind pumps: Performance analysis, design concept and testing; Principle of Wind Energy Generators; Stand alone, grid connected and hybrid applications of WECS; Economics of wind energy utilization; Wind energy in India; Case studies.

Unit V. Small Hydropower Systems [14]

Overview of micro, mini and small hydro systems; Hydrology; Elements of pumps and turbine; Selection and design criteria of pumps and turbines; Site selection and civil works; Speed and voltage regulation; Investment issues load management and tariff collection; Distribution and marketing issues: case studies; Potential of small hydro power in India.

Reference Books:

1. Wind Energy Explained: Theory, Design and Application, by J. F. Manwell, ISBN:9780470015001, Publisher: John Wiley & Sons, Publication Date: February 2010
2. Introduction to Wind Energy Systems: Basics, Technology and Operation (Green Energy and Technology), by Hermann-josef Wagner, ISBN: 9783642020223, Publisher: Springer, September 2009.
3. Wind Energy (Fueling the Future), by Lola Schaefer, ISBN:9781432915728, Publisher:Heinemann Educational Books, 2008.
4. Wind Turbines: Fundamentals, Technologies, Application and Economics, Erich Hau , Springer Verlag; (2000)
5. Wind Energy Explained , J. F. Manwell, J. G. McGowan, A. L. Rogers, John Wiley & Sons; 1st edition (2002)
6. Wind Energy Handbook , Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi, John Wiley & Sons; 1st edition (2001)
7. Wind and Solar Power Systems , Mukund R. Patel, CRC Press; (1999)
8. Mini Hydropower , Tong Jiandong(et al.) , John Wiley, 1997

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