PONDICHERRY UNIVERSITY

(A Central University)

R.V. NAGAR, KALAPET, PUDUCHERRY – 605 014 INDIA

DEPARTMENT OF GREEN ENERGY TECHNOLOGY

MADANJEET SCHOOL OF GREEN ENERGY TECHNOLOGIES

SYLLABUS

M.TECH. GREEN ENERGY TECHNOLOGY

2022-2023

DEPARTMENT OF GREEN ENERGY TECHNOLOGY

MADANJEET SCHOOL OF GREEN ENERGY TECHNOLOGIES

PONDICHERRY UNIVERSITY, PONDICHERRY – 605 014, INDIA

M.TECH. IN GREEN ENERGY TECHNOLOGY

The field of Green Energy Technology (GET) encompasses a continuously evolving group of methods, materials, and processes, from environmentally benign techniques for generating energy to its minimal utilization for maximal production of end materials and utilization of waste products when generated. The goals of this rapidly growing, highly interdisciplinary field include i). sustainability - meeting the needs of society in ways that without damaging or depleting natural resources, ii). innovation - developing alternatives to technologies to those that have been demonstrated to damage health and the environment and source reduction – and iii). reducing waste and pollution by changing patterns of production and consumption. Thus, Green Technology is a term used to describe the production of knowledge-based products or provide services that improve operational performance, productivity, or efficiency, while reducing costs, inputs, energy consumption, waste, and pollution.

M.Tech. offered at Pondicherry University in Green Energy Technology is a cutting-edge material-based program designed to equip post-graduates with multi-disciplinary skills and knowledge in the areas of green energy generation and green processes in chemical and construction industries, applications of nanotechnology, waste management, and environmental sustainability, etc. The course will be taught by a team of specialists working in the fields of green energy technology, chemical science, biological science, project management, and environmental policy. This program is designed for two years, spread into four semesters. The first two semesters are for hard and softcore courses, the third semester is entirely for soft-core (optional) courses, and the final semester is for a project. Many soft-core courses are stand-alone so that they can be taken at any time offered by the Department. In addition, there will be some bridge courses. Most of the first semester courses will be on energy and modeling. The second and third-semester courses will be based on energy, environment, chemistry, management, and other GET-related fields. Students will select courses suiting backgrounds and interests. Each theory course will have a project component which will be either individual or group-based. **Students will be required to earn at least 87 credits to qualify for the M.Tech. Degree.** Students with Bachelor's in Engineering or Master's in Material Science, Physical Sciences, Chemical Sciences, Biological Sciences or equivalent degree, with at least 55% marks or equivalent grades in the qualifying examination, excepting M.Sc. IT and B.E/ B.Tech IT, are eligible to undergo this program. The detailed degree-wise eligibility criterion is separately given at the end.

The following are the thrust areas of our Department currently focused on teaching and conducting research:

- Photovoltaic Technology
- Solar Thermal Energy Technology
- Bioenergy / Biofuels /Combustion Technology
- Energy Materials/Energy Conversion & Storage
- Green Building/Sustainable Technology
- Wind/Ocean/Tidal Energy Technology
- Organic Photovoltaics and Green Chemical Technologies
- Computational in Energy Technology

Subject areas covered in M.Tech. Green Energy Technology program are:

Energy Courses on energy include the development of alternative fuels, new means of generating energy, energy efficiency, storage and distribution, modeling, and waste management.

1. **Energy, Environment, renewable energy, and sustainable development:** This course focus on the fundamentals of energy, environment, renewable energy, and sustainable development. This course will give an overview of the energy scenario in the national and global level.

2. **Modelling and simulation** allow engineers to reason about the expected behavior of a system without having to physically implement it. Simulation pervades much of engineering to build models of individual devices, circuit simulation, networks, and physical systems for control purposes. The course is intentionally designed to have a strong practical focus, with extensive laboratory work serving to develop key skills with the aim to enable students to use Modelling and Simulation in the design and verification of Renewable and Green Energy systems. Green Economics this subject involves the search for products whose contents and methods of production have the smallest possible impact on the environment.

3. **Processing energy harvesting materials is** an essential part of Green Energy Technology. Course indents to introduce the material selection criteria and material processing techniques to the M.Tech. students.

4. **Solar Thermal Technology & Energy Conversion Systems** aims to provide understanding of the solar thermal energy conversion processes, storage and the utilization of solar thermal energy. Student will acquire knowledge on the various types of collectors, concentrators, thermal power plants design and thermal energy storage concepts.

5. **Wind/Ocean/Tidal Energy Technology/ Small Hydropower Systems**
The student will get the understanding on the source of energy in the wind, its characterization and various methods of harnessing the same. Detail theoretical understanding on design and characterization of wind energy conversion system with particular reference to electrical machines & turbines is emphasized. In the other part of the course, fundamentals of energy generation from hydro

power and small hydro power plant concepts are discussed. Students will also get exposure in terms of case studies on wind and hydrothermal power plant. To acquire knowledge about generation of electric energy from ocean waves with emphasis on technical aspects but also with respect to environmental effects and system properties.

6. **Bio-energy and conversion systems** deal with biomass resource estimation and management, various energy conversion technologies and methods to generate energy from waste. Specifically, microalgal biomass culture, harvest, catalytic deconstruction, biofuel conversion and its characterization, bioprospecting of lignocellulosic resource for bio-energy and other value added products.

7. **Photovoltaic energy conversion** principles, required materials and device structures **-** characterization techniques and quality analysis. Installation and maintenance of SPV power systems – Knowledge on power systems components and economic aspects SPV power systems.

8. **Nanotechnology for energy harvesting** starts with the basic nano-electronics and elaborates to the size and shape depended properties of nanomaterial. Then it focuses towards the energy harvesting with nanomaterials and also explains how the nanomaterial properties can be tuned for energy storage and energy efficiency. Theoretical, computational and project based activities are included in the course.

9. **Electrochemical Energy Conversion and Storage:** From the basics to technologies on electrochemical energy conversion & storage will be taught which includes various types of batteries, supercapacitors and fuel cells.

10. **Green Building and Sustainable Development**: Concept of Green building, Principles of green buildings, Eco-friendly materials, Certification systems – Green Rating for Integrated Habitat Assessment (GRIHA) and Leadership in Energy and Environmental Design (LEED), etc.

11. **Computational in Energy Technology**
To develop an understanding of the major approaches and methodologies used in CFD, the interplay of physics and numerical, the methods and results of numerical analysis. Also, to help the student gain experience in the actual implementation of numerical methods in energy engineering, implementing and using basic CFD methods, the main emphasis is on practical use of codes based on Finite Element/Volume methods for subsonic incompressible and compressible recirculating flows.

12. **Green chemical science and technology for the sustainable future:**
Aims to provide the understanding and importance of practicing the green chemistry and green chemical technologies in the preparation of materials and manufacturing of the devices for energy applications in a most viable way. Further will understand the application of the same in process integration for zero/ minimum waste, and generating value from waste.

13. **Research and Business Skills,** Project and Portfolio Management Development of research, communication and project management skills.

14. **Energy Laboratories:** Students will be taught green energy experiments which involve

estimation of calorific values of a fuel, studying solar radiation, assembling solar still, and solar water hear, fuel cell performance and simulation/ modelling of few energy devices, etc. In semester I, II & III, energy laboratory course will be offered.

15. Mini-project and Proposal Writing: All students will do a mini-project which involves taking up a small green energy project within campus or outside and learning about how to communicate the data to scientific journals.

16. Green Energy Technology Dissertation & Viva-voce: Specifically designed to give the student practical experience in technologies and principles appropriate to developing a green technology. The student will undertake a research based project at Pondicherry University or at an associated academic or industrial partner and thus receive practical training in chosen area from an expert.

In addition to above, courses will be added time to time based on developments in this fast emerging field.

Teaching and Learning Methods Lectures, tutorials and seminars form the main methods of course delivery enhanced by individual and group project work, laboratory work, computing workshops and industrial visits.

Assessment Methods Teaching and assessment will be by Choice Based Credit System (CBCS). Evaluation will be through session (laboratory reports, class tests, set assignments) or by continuous assessment (designing, computer practical, seminar papers, project reports etc.) and end-semester examinations.

<u>The pattern of end-semester examination shall be broadly as per the following:</u>

End Semester Theory Examination (Total Marks = 60)
Part A: Answer All the Questions. Five questions of 2 marks each (5 x 2 = 10).
Part B: Answer Any 5 questions out of 6. Each question carry 4 marks (5 x 4 = 20).
Part C: Descriptive. Answer any 5 questions out of 8. Each question carry 6 marks (5 x 6 = 30).

Each question may contain sub-divisions a, b, c etc.

End Semester-Practical Examination (Total Marls = 60)

<u>Evaluation pattern:</u>
Experiment / Demo 20 Marks. Procedure / Result 20 Marks. Viva 20 Marks.

<u>Internal Examinations:</u> Examinations are conducted in a semester for 40 Marks.
Written Examination 30 Marks and Assignment /Seminar 10 Marks.

<u>Employment:</u> It is envisaged that the M.Tech. Graduates in Green Technology will gain employment in the Engineering Industry with many companies now seeking to exploit the benefits of Green Technology products and processes.

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M.Tech. GREEN ENERGY TECHNOLOGY - Program Specific Outcome:

1. Trained man powers in the area of major renewable and clean energy technologies.
2. Acquiring specialization in the chosen field of renewable energy through industrial training and/or research work.
3. Acquire knowledge on energy generation, including design, fabrication, testing, and modeling of the process.
4. Gaining a specific understanding on fabrication and evaluation of solar cells, batteries, super capacitors and fuel cells.
5. Gaining specific understanding of the design and installation of PV power plants and solar thermal devices.
6. Specific understanding of biodiesel, bioethanol, and biogas production.
7. Specific understanding of the conversion of waste to energy and harnessing energy from the wind.
8. Gained knowledge of energy audit and management.
9. Trained man powers on building sustainability on society and environment.
10. Gained knowledge on the art of scientific writing, publishing and presenting.

M.Tech. Green Energy Technology – Distribution of the Hardcore and Softcore credits

SEMESTER	HARDCORE	SOFTCORE	TOTAL
SEMESTER – I	21	03	24
SEMESTER – II	21	06	27
SEMESTER – III	06	18	24
SEMESTER - IV	12	-	12
TOTAL CREDITS	**60**	**27**	**87**

M.Tech. Green Energy Technology – Eligibility criteria for admission

Program details	Eligibility for Admission to M.Tech. Programme
M.Tech. (Green Energy Technology)	**B.E./B.Tech.** in Mechanical/Electrical/Electronics/Civil/Energy/Chemical or Biotechnology/Environmental Engineering with at least 55% in the qualifying examination. **OR** **M.Sc.** in Physics/Chemistry/Material Science/Nanoscience/Bioenergy/ Photonics/Biotechnology/Environmental Science with Mathematics at B.Sc. level with at least 55% in the qualifying examination.

M.Tech. Green Energy Technology – Eligibility criteria of the International students admitted under SAF Fellowship, and ICCR Scholarship, etc.

Program details	Eligibility for Admission to M.Tech. Program
M.Tech. (Green Energy Technology)	**B.E./B.Tech.** in Mechanical/Electrical/Electronics/Civil/Energy/Chemical or Biotechnology/Environmental Engineering with at least 55% in the qualifying examination. **OR** **M.Sc**. in Physics/Chemistry/Material Science/Nanoscience or Bioenergy/ Photonics/Biotechnology/Environmental Science with Mathematics at B.Sc. level with at least 55% in the qualifying examination. **OR** Four years of Engineering programs under a 10+2+4 pattern of education with any of the following engineering specializations or their equivalent: Electrical, Electronics, Mechanical, Materials, Geology, Hydrometeorology, Civil, Biotechnology, Chemical, Environmental. **OR** Post-graduate degree in Science under 10+2+3+2 years of study or its equivalent with specialization in any of the following disciplines: Physics, Chemistry, Materials Science, Nanoscience, Biotechnology. Any other equivalent qualification claimed for admission shall be decided by the faculty of DGET as per the guidelines of the Association of Indian Universities.

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SEMESTER-I

Course Code	Course Title	Course Type*	L	T	P	C
	Hard-Core Course					
DGET511	Energy, Environment and Renewable Energy Technologies	H	3	1	0	3
DGET512	Bioenergy and Conversion Systems	H	3	1	0	3
DGET513	Fuels, Combustion and Cleaner Technology	H	3	1	0	3
DGET514	Computational Fluid Dynamics for Energy Engineering	H	3	1	0	3
DGET515	Solar Thermal Energy Conversion	H	3	1	0	3
DGET516	Modelling and Simulations of Green Energy systems	H	3	1	0	3
	Soft-Core Courses*					
DGET517	Electrical Energy Systems **	S	3	0	0	3
DGET518	Nanomaterials: Properties, Synthesis, Characterization and applications	S	3	0	0	3
	Practical					
DGET510	Energy Laboratory –I	H	0	2	4	3

Total Credits: 24

* A minimum of one soft-core should be taken
**Mandatory for Non-Electrical students

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SEMESTER-II

Course Code	Course Title	Course Type*	L	T	P	C
Hard-core Course						
DGET521	Solar Photovoltaic Energy Conversion	H	3	1	0	3
DGET522	Electrochemical Energy Conversion and Storage	H	3	1	0	3
DGET523	Wind Energy Technology	H	3	1	0	3
DGET524	Bioprocess Engineering for Biofuels	H	3	1	0	3
DGET525	Solar Thermal Devices and Thermal Energy Storage	H	3	1	0	3
DGET526	Green Building and Sustainable Development	H	3	1	0	3
Soft-core courses*						
DGET527	Solid Waste Management to Energy Conversion	S	3	0	0	3
DGET528	Nanotechnology for Solar Energy Systems	S	3	0	0	3
DGET529	Carbon Sequestration at the Landscape level	S	3	0	0	3
DGET530	Microbial Technology for Biofuel Production	S	3	0	0	3
DGET531	Green Chemical Technologies	S	3	0	0	3
Practical						
DGET520	Energy Laboratory –II	H	0	2	4	3

Total Credits: 27

*At least two soft-core courses should be taken.

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SEMESTER-III

Course Code	Course Title	Course Type*	L	T	P	C
	Hard-core Course					
DGET611	Research Methodology & Mini-project	H	3	1	0	3
	Soft-core Courses*					
DGET612	Solar Photovoltaic Power Systems	S	3	0	0	3
DGET613	Artificial Intelligence, Machine Learning and Data Analysis for Photovoltaic Systems	S	3	0	0	3
DGET614	Advance Materials for Renewable Energy Systems	S	3	0	0	3
DGET615	Industrial Energy Audit and Management	S	3	0	0	3
DGET616	Advanced Battery and Fuel Cell Technologies	S	3	0	0	3
DGET617	Electric Vehicle Technology	S	3	0	0	3
DGET618	Advanced Wind Energy Conversion System	S	3	0	0	3
DGET619	Bio refineries	S	3	0	0	3
DGET620	Anaerobic Digestion and Biogas Technology	S	3	0	0	3
DGET621	Alternate Materials for Sustainable Technology	S	3	0	0	3
DGET622	Biomass Feedstock and Solid Biofuel Production	S	3	0	0	3
DGET623	Organic Photovoltaics	S	3	0	0	3
	Other Department's Softcore papers**	S	3	0	0	3
	Practical					
DGET610	Energy Laboratory – III (Virtual Instrumentation and Case Study on Sustainable Energy Systems)	H	0	2	4	3

Total Credits: 24

*At least six soft-core courses should be taken.
** Maximum of 2 Soft-Core courses offered by other departments at PG level with recommendation of the faculty adviser.

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SEMESTER-IV

Course Code	Course Title	Course Type*	L	T	P	C
DGET640	Green Energy Technology Dissertation & Viva-Voce	H	Full Semester			12
Total Credits (I+II+III+IV Semesters)						**87**

H – Hard-core Course; S - Soft-core Course, L – Lecture; T – tutorial; P – Practical; C – No. of Credits

Evaluation:
All theory, practical and dissertation courses have an Internal Assessment of 40 Marks and External Assessment of 60 Marks.

OTHER SOFT-CORE COURSES

These courses will be offered in any of the first three semesters depending on the availability of the resource faculty.

Course Code	Course Title	Course Type*	L	T	P	C
DGET624	Green Management	S	3	0	0	3
DGET625	Bio Industrial Skills	S	3	0	0	3
DGET626	Bioprospecting Technology for Biofuel production	S	3	0	0	3
DGET627	Micro Hydropower Energy System	S	3	0	0	3
DGET628	Sustainable Technologies for Valorization of Waste Carbon Feedstocks	S	3	0	0	3

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SEMESTER-I

DGET511: ENERGY, ENVIRONMENT AND RENEWABLE ENERGY TECHNOLOGIES

(Hard-core Course) **L T P C**
3 1 0 3 45L

Course Outcome:

- Understand the nexus between energy, environment and sustainable development
- Appreciate energy ecosystems and its impact on environment
- Learn basics of various types of renewable and clean energy technologies
- Serve as bridge to advanced courses in renewable energy

Unit I: Energy [8]

Introduction to the nexus between energy, environment and sustainable development, Energy sources over view and classification, sun as the source of energy, fossil fuel reserves and resources - overview of global/ India's energy scenario. Energy consumption models – Specific Energy Consumption.

Unit II: Ecology and Environment [9]

Concept and theories of ecosystems, - 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 the environment - environmental laws on pollution control, The environmental protection act: Effluent standards and ambient air quality, innovation and sustainability, eco-restoration: phyto-remediation.

Unit III: Renewable Sources of Energy [10]

Solar Energy: Solar radiation: measurements and prediction. Indian's solar energy potential and challenges, solar energy conversion principles and technologies: Photosynthesis, Photovoltaic conversion and Photo thermal energy conversion. **Wind Energy**: Atmospheric circulations, atmospheric boundary layers, classification, factors influencing wind, wind shear, turbulence, wind energy basics and power Content, wind speed monitoring, Betz limit, wind energy conversion system: classification, characteristics and applications. **Ocean Energy**: Ocean energy resources-ocean energy conversion principles and technologies: ocean thermal, ocean wave & ocean tide. **Bioenergy:** resources and types.

Unit IV: Other Energy Sources and Systems [9]

Hydropower, Nuclear fission and fusion-Geothermal energy: Origin, types of geothermal energy sites, site selection, geothermal power plants; hydrogen energy, Magneto-hydro-dynamic (MHD) energy conversion – Radioisotope Thermoelectric Generator (RTG), Bio-solar cells, battery & super capacitor, energy transmission and conversions.

Unit V: Energy and Economy [9]

Energy and Economics: gross domestic product (GDP) and energy – energy market and society – energy efficiency – energy – energy and economics – energy: security – equity – environmental sustainability index and global measure

Text Books:

1. Energy and Environment Set: Mathematics of Decision Making, Loulou, Richard; Waaub, Jean- Philippe; Zaccour, Georges (Eds.), 2005.
2. Energy and the Environment, Ristinen, Robert A. Kraushaar, Jack J. AKraushaar, Jack P. Ristinen, Robert A., 2nd Edition, John Wiley, 2006.

References:

1. Energy and the Challenge of Sustainability, World Energy assessment, UNDP, N York, 2000.
2. Solar Energy: principles of Thermal Collection and Storage, S.P. Sukhatme, Tata McGraw-Hill (1984).
3. D. Y. Goswami, F. Kreith and J. F. Kreider, Principles of Solar Engineering, Taylor and Francis, Philadelphia, 2000.
4. Wind Energy Conversion Systems, L.L. Freris, Prentice Hal 1990.
5. Geothermal Energy: From Theoretical Models to Exploration and Development by Ingrid Sober and Kurt Bucher, Springer, 2013.
6. Ocean Energy: Tide and Tidal Power by R. H. Charlier and Charles W. Finkl, Springer 2010

DGET 512: BIOENERGY AND CONVERSION SYSTEMS

(Hard-core Course) **L T P C**
3 1 0 3 **45L**

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
- Understanding of various types of bioenergy conversion systems in practice
- Acquire basic knowledge on microbial culture, biomass harvest and biofuel production
- Know the national and international biofuel Standards.

Unit I: Biological Systems [10]

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. From biomolecules to cells - biological systems. Biomass mass resources.

Unit II: Biochemical Pathways and Chemical Kinetics: [8]

Biosynthesis and breakdown of carbohydrates- Lipids- proteins and nucleic acids TCA cycle - Glycolysis - Gluconeogenesis - Pentose phosphate shunt - Urea cycle - Interconnection of Pathways - Metabolic regulations. Biocatalysis by enzymes and pathways - Fermentation bioethanol and biobutanol – Rate limiting steps and conversion efficiency.

Unit III: Biomass Resources and Biochemical Conversions [10]

Microbial biomass. Large scale culture and harvest of photosynthetic organism - photo bioreactors; Microalgae for lipid and carbohydrate synthesis. 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 IV: Thermochemical & Chemical Conversions [9]

Thermochemical Conversion: Direct combustion, incineration, pyrolysis, gasification and liquefaction; Bio gasification: Biomethanation process, biogas digester types,. Waste to energy. Chemical Conversion: Hydrolysis & hydrogenation; solvent extraction of hydrocarbons; solvolysis of wood, bio crude, biodiesel production via chemical process; transesterification methods; Chemicals from biomass.

Unit V: Biofuels Standards & Power Generation [8]

Physical and chemical characteristics of biofuels – Biomass, wood gas, bio methane; ethanol, biodiesel, Wood oil; Bio blends - Indian and International standard specifications. Adaptation of biofuel in various applications. Biofuel economy; Biofuel roadmap of India - policy issues, regulatory issues and economic impact; Entrepreneurship in biofuel - Prospects & Challenges, Case studies.

Text Books:

1. Renewable Energy, Third Edition, Bent Sorensen, Academic Press August 2004
2. Lehninger's Principles of Biochemistry by David L. Nelson and Michael M. Cox, Macmillan Worth publisher, 2009.

Reference books:

1. Biochemistry 6th edition by Jeremy M Berg, Lubert Stryer, John L. Tymoczko, 2008.
2. Voet and Voet's Biochemistry, D. Voet and J. Voet 3rd Edition, John Wiley and Sons Inc., 2005.
3. Biochemistry, 5th Ed by Eric E Conn, Paul K Stumpf, George Bruening and Roy H Doi, 2009.
4. Biofuels - Securing the Planet's Future Energy Needs, Edited by A Demirbas Springer 2009.
5. Biomass Assessment Handbook - Bioenergy for a sustainable environment Edited by Frank Rosillo-Calle, Sarah Hemstock, Peter de Groot and Jeremy Woods, Earthscan November 2006.
6. Dictionary of Renewable Resources - 2nd Edition, Revised and Enlarged, Zoebelein, Hans, Wiley-VCH, 2001.

DGET 513: FUELS, COMBUSTION AND CLEANER TECHNOLOGY

L T P C

(Hard Core Course) **3 1 0 3** **45L**

Course Outcome:

Students will learn about

- Basics of solid, liquid and gaseous fuels
- Conversion of solid fuels to liquid and gases fuels
- Petroleum refinery processes in detail
- Combustion stoichiometry and flue gases analysis and
- Industrial furnaces, advance clean coal technologies and carbon-di-oxide capture and storage.

Unit I: Solid Fuels [9]

Coal: Family, origin, classification of coal, coal rank-Hilts law analysis, physical and chemical properties of coal; Calorific value of solid fuels- Action of heat on coal; Liquefaction of coal, direct and indirect liquefaction, Fischer-Tropsch synthesis. Gasification processes of coal- Lurgi and Winkler. Manufactured fuels- hard and soft coke, Agro fuels-solid fuel handling and storage.

Unit II: Liquid and Gaseous Fuels [9]

Origin and classification of petroleum crude oil; recovery of crude oil, properties – flash/fire point, octane and cetane number. Oil refinery -physical, chemical and catalytic processes –distillation, vacuum distillation, catalytic reformer, catalytic hydrotreater, upgrading heavy oil, thermal cracking, catalytic cracking, dewaxing, deasphalting and catalyst rejuvenation. Liquid fuels from other sources; Storage and handling of liquid fuels. Types of gaseous fuels: natural gases, methane from coal mines, manufactured gases, producer gas, water gas, biogas, refinery gas, LPG; Cleaning and purification of gaseous fuels.

Unit III: Theory of Combustion Process [9]

Combustion: Concept, 3Ts, ignition, auto- and force ignition. Burners and basic features/design of burners for solid, liquid, and gaseous fuels. Combustion Stoichiometry and thermodynamics. Heat of reaction, of higher heating value (HHV), lower calorific value (LHV), determination of calorific value by Bomb Calorimeter and Boy's calorific methods.

Unit IV: Fuel stoichiometry and analysis [9]

Stoichiometry: Estimation of air required for complete combustion. Mass basis and volume basis, air to fuel ratio, rich and lean mixture, excess air calculation. Estimation of minimum amount of air required for a fuel of known composition. Estimation of dry flue gases and exhaust gases analysis, Orsat flue gas analyzer. Calculation of the composition of fuel & excess air supplied from exhaust gas analysis. Dew point of products; Flue gas analysis (O_2, CO_2, CO, NOx, SOx).

Unit V: Industrial furnaces and advance clean technology [9]

Industrial furnaces: Blast furnace and Open-hearth furnace for metal extraction. Heat distribution in furnaces and waste heat recovery: Recuperates and regenerators. Furnace insulation: Ceramic coating. Advance clean coal combustion and gasification and co-gasification: Pulverized, fluidized bed combustion, and recent advance technologies. Emission reduction and carbon-di-oxide capture and storage.

Text Books:

1. Fuels and Combustion, Samir Sarkar, Orient Longman Pvt. Ltd, 3rd edition, 2009
2. S.P. Sharma &Chander Mohan, Fuels & Combustion, Tata McGraw Hill Publishing Co.Ltd.,1984.

Reference Books:

1. K. Kanneth, "Principles of combustion", Wiley and Sons, 2005.
2. Liquid Fuels for Internal Combustion Engines: A Practical Treatise for Engineers & Chemists, by Harold Moore, ISBN: 9781146203067, Publisher: Nabu Press, 2008.
3. Cleaner Combustion and Sustainable World-HaiyingQi, Bo Zhao, Springer 2013.
4. Fuel Flexible EnergyGeneration, Solid, Liquid and Gaseous Fuels by John Oakey, Woodhead Publishing – Elsevier, 2016.
5. An introduction to combustion: Concept and applications – Stephen R Turns, Tata Mc. Graw Hill, 3rd edition, 2012
6. Modern Petroleum Technology, Vol 1, Upstream, Ed. by Richard A. Dave, IP, 6th ed.,John Wiley & Sons. Ltd

DGET 514: COMPUTATIONAL FLUID DYNAMICS FOR ENERGY ENGINEERING
(Hard-core Course) **L T P C**
3 1 0 3 45L

Course Outcomes

At the end of the course students should be able to:

- Describe the physical significance of each term in the governing equations for CFD.
- Effectively use a commercial CFD package to solve practical CFD problems.
- Quantify and analyze the numerical error in solution of the CFD, PDE's.
- Formulate explicit and implicit algorithms for solving the Navier Stokes Equations.
- Create and demonstrate verification strategies for evaluating CFD application in Energy Engineering.

Unit I: Governing Equations and Boundary Conditions [9]

Basics of computational fluid dynamics – Governing equations of fluid dynamics – Continuity, Momentum and Energy equations – Chemical species transport – Physical boundary conditions – Time-averaged equations for Turbulent Flow – Turbulent–Kinetic Energy Equations – Mathematical behavior of PDEs on CFD – Elliptic, Parabolic and Hyperbolic equations.

Unit II: Finite Difference & Finite Volume Methods for Diffusion [9]

Derivation of finite difference equations – Simple Methods – General Methods for first and second order accuracy – Finite volume formulation for steady state One, Two and Three -dimensional diffusion problems –Parabolic equations – Explicit and Implicit schemes – Example problems on elliptic and parabolic equations – Use of Finite Difference and Finite Volume methods.

Unit III: Finite Volume Method for Convection Diffusion [9]

Steady one-dimensional convection and diffusion – Central, upwind differencing schemes properties of discretization schemes – Conservativeness, Boundedness, Transportiveness, Hybrid, Power-law, QUICK Schemes.

Unit IV: Turbulence Modelling [10]

Important features of turbulent flow, Vorticity transport equation, Statistical representation of turbulent flows: Homogeneous turbulence and isotropic turbulence, General Properties of turbulent quantities, Reynolds average Navier stokes (RANS) equation, Closure problem in turbulence: Necessity of turbulence modelling, Different types of turbulence model: Eddy viscosity models, Mixing length model, Turbulent kinetic energy and dissipation, The κ-ε model, Advantages and disadvantages of κ -ε model, More two-equation models: RNG κ-ε model and κ-ω model, Reynolds stress model (RSM),Large eddy Simulation (LES),Direct numerical simulation (DNS).

Unit-V: Application of CFD in WIND, PV and Battery/Fuel Cells Energy Syste [8]

Application of CFD in Wind Energy, Different load configurations (Aerodynamic load, gravity loads, centrifugal loads, wind Shear), Co-efficient of pressure, Kinetic Energy of wind, momentum in the wind, Power, Coefficient of Power. Application of CFD in Photo Voltaic Energy System. Application of CFD in Battery/Fuel Cells.

Text Books:

1. Computational Fluid Flow and Heat Transfer, K. Muralidhar, T. Sundararajan (Narosa Publication).
2. Computational Fluid Dynamics by Chung T. J., Cambridge University Press.

Reference Books:
1. Numerical Heat Transfer and Fluid Flow by S. V. Patankar
2. Essential Computational Fluid Dynamics by Zikanov. O., Wiley
3. Computer Simulation of Flow and Heat Transfer by P. S. Ghoshdastidar (4th Ed, Tata McGraw-Hill).
4. Computational Fluid Dynamics by Tapan K. Sengupta, University Press.
5. Numerical Computation of Internal and External Flows by Hirch C., Elesvier.

DGET 515: SOLAR THERMAL ENERGY CONVERSION

(Hard Core Course) **L T P C**
3 1 0 3 **45L**

Course Outcome:

- To acquire knowledge on solar radiation and its characteristics
- To develop understanding the importance of heat transfer in solar thermal energy studies
- To analyze the thermal characteristics of solar flat plate collectors
- To study solar concentrating collectors and its features

Unit I: Solar Radiation Geometry [10]
Solar angles; the earth and solar constant; day length; angle of incidence on the 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: Heat transfer: Concepts and Definition [7]
Introduction; Heat transfer in engineering; Mechanism of heat transfer; Temperature field and temperature gradient; Conduction; Thermal Conductivity; Thermal insulation; Contact resistance; Convection; Thermal radiation; Combined mechanism of heat transfer, Thermal contact resistance; Critical thickness of insulation; Conduction in other shapes; Shape factor; Steady state heat conduction in solid/hollow cylinders with uniform heat generation

Unit III: Heat Transfer and Fluid Flow Correlation for Design of Solar Thermal Systems [8]
Heat Exchangers; Overall heat transfer coefficient; Log mean temperature difference; Heat exchanger performance: Effectiveness; Fins; Fin model; Temperature calculation; Heat flow calculation; Fin performance: Fin effectiveness, Fin efficiency; Application of fins in enhanced heat transfer; Mechanism of convection, Free convection (Laminar, Turbulent &Mixed) on horizontal, vertical and Inclined plates, cylinder and sphere; forced convection inside tube sand ducts; Forced convection over exterior surfaces; Dimensionless group of importance of heat transfer and fluid flow.

Unit IV: Solar Flat Plate Collectors [12]
Flat plate collectors; Basic flat-plate energy balance; Effective energy losses; Thermal analysis; Heat capacity effect; overall loss coefficient; Collector efficiency factor; Collector heat removal factor; efficiency of flat plate collectors; Effective transmittance-absorptance product; Evacuated tube collectors: Types, thermal analysis; Materials for solar flat plate collectors; Selective coating.

Unit V: Solar Concentrating Collectors [8]
Concentrating collectors: Designing and types; Acceptance angle; Geometric concentration ratio; Optical efficiency; Thermal efficiency; Classification, Types of concentrators; Materials for solar concentrators.

Text Books:

1. DuffleandBeckman,SolarThermalEngineeringProcess,JohnWiley&Sons,NewYork
2. J.S.Hsieh,SolarEnergy,PrenticeHall Inc.NewJerssey

Reference Books:

1. P.J.Lunde,SolarThermalEngineering,JohnWiley&Sons,NewYork
2. N.C.Harris, C.E.MillerandI.E.Thomas,Solar EnergySystemsDesign, JohnWiley&Sons,NewYork
3. Garg HP.,PrakashJ.,SolarEnergy:Fundamentals&Applications,TataMcGrawHill,NewDelhi,1997
4. S.P.Sukhatme,SolarEnergy,TataMcGrewHill CompanyLtd., NewDelhi
5. F.KreithandJ.F.Kreider,PrinciplesofSolarEngineering,HemispherePublishingCoro.
6. A.B.MeinelandM.B.Meinel,AppliedSolarEnergy,Addison– WileyPub.Co.,Reading

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DGET516: MODELLING AND SIMULATIONS OF GREEN ENERGY SYSTEMS

(Hard Core Course) **L T P C**
3 1 0 3 45L

Course Outcome:

- To provide a basic understanding of Probability Theory
- To provide a basic understanding of applied Linear Algebra and optimization problems, viz., their formulation, analytic and computational tools for their solutions,
- To learn about applications of Linear Algebra and Probability Theory in modelling and simulation environment.

Unit I: Introduction to mathematical modelling [9]

Introduction to mathematical modelling: Basic principles of modeling, Physical and mathematical models, Fundamentals of Programming: Introduction to computational softwares: Programming in computational software (with the help of a specific software Matlab or python), Elementary computer graphics, Numerical integration –Differentiation, Newton forward, backward and central difference, trapezoidal and Simpson methods, Newton-Raphson.

Unit II: Date, Script and Function Files [9]

Handling data files, Script files and Function files, User Defined Function files, physical model-Solar simulator, computer simulation of solar radiation, estimation of solar constant, ASHRAE radiation model and simulation of clear sky solar radiation.

Unit III: Scripts and Models [9]

Lab exercises to develop simple Scripts and models related to building energy systems involving applications of data analysis, solar cell I-V curve analysis, diode model and simulation, solar cell model, simple photovoltaic models and simulation, Flat Plate Collector (FPC) model.

Unit IV: Power Electronic System Modeling [9]

Power electronic system modeling, Model files, Basic elements-: blocks and lines.-Running Simulation-Building Systems- Block Libraries: Sources, Sinks, Discrete, Linear. Nonlinear, Connections, Defining Block Parameters Using Matlab, buck and boost converters, DC-AC inverter(with the help of any one of Simulink), implementation of MPPT.

Unit V: Modelling and Simulation of Solar, Wind and Hybrid systems [9]

Optimization and curve fitting techniques, least square methode, lagrange multiplier, interpolation techniques, newtons and lagrange interpolations, FPC optimization, Modelling of PV Solar Array: simulation of power output of PV systems, Wind TurbineTurbine/generator, Hybrid system modelling.

Text Books:

1. Modelling and Simulation: Exploring Dynamic System Behaviour, by Louis G. Birta Publisher: Springer, 2007
2. An Engineer's Guide to MATLAB: With Applications from Mechanical, Aerospace, Electrical, and Civil Engineering E. B. Magrab S. Azarm B. Balachandran J. H. DuncanbK. E. Herold G. C. Walsh Prentice Hall 2004

Reference Books:

1. Solar Photovoltaics, Fundamentals, Technologies and Applications, C.S. Solanki, Eastern Economy Edition, Third Edition, 2016, Academic Press 2007
2. G.M.Masters, Renewable and Efficient Electric Power Systems, Wiley, first edition, 2004.
3. Modeling of photovoltaic system using MATLAB: simplified Green Codes, Tamer Khatib, Wilfried Elmenreich, First Edition, Wiley, 2016

DGET 517: ELECTRICAL ENERGY SYSTEMS

L T P C

(Soft Core Course) **3 0 0 3**

45L

Course Outcome:

- To explain DC circuits, AC circuits and the behavior of R, L and C and their combinations in AC circuits.
- To discuss three phase balanced circuits.
- To explain principle of operation, construction and performance of electrical machines such as single-phase transformer, DC machines, synchronous generator and three phase induction motor.
- To introduce concepts of electrical wiring, circuit protecting devices and earthing, understand Electrical Equipment's used in Power Plants, Electrical Power System Analysis, Power Transmission

Unit I: Introduction to Basics of Electrical Systems [8]

D.C. Circuits: Analysis of series, parallel and series- parallel circuits excited by independent voltage sources. Power and Energy.

A.C. Fundamentals: Generation of sinusoidal voltage, frequency of generated voltage, definition and numerical values of average value, root mean square value, form factor and peak factor of sinusoidally varying voltage and current.

Single Phase Circuits: Analysis, with phasor diagram, of circuits with R, L, C, R-L, RC, R-L-C for series and parallel configurations. Real power, reactive power, apparent power, and power factor.

Three Phase circuits: Generation of 3-phase power, Three-phase balanced circuits, voltage and current relations in star, delta connections and Measurement of three phase.

Unit II: Transformers, DC Generators and Motors [8]

Single Phase Transformers: Construction and types of transformers, Principle of operation, emf equation, losses, variation of losses with respect to load, efficiency, Condition for maximum efficiency.

DC Generators: Principle of operation, Construction of D.C. Generators. Expression for induced emf, Types of D.C. Generators, Relation between induced emf and terminal voltage.

DC motors: Principle of operation, Back emf, Torque equation, Types of dc motors, Characteristics of dc motors (shunt and series motors only) and Applications.

Unit III: Synchronous Generators and Induction Motor [8]

Three Phase Synchronous Generators: Constructional details, Synchronous speed, Frequency of generated voltage, emf equation, Concept of winding factor.

Three Phase Induction Motors: Generation of rotating magnetic field, Three-phase induction motor, Slip and its significance. Necessity of starter, star-delta starter.

Unit IV: Electrical equipment used in Power Plants [6]

Electrical Equipment's used in Power Plants, Electrical Power System Analysis, Power Transmission.

Text Books:

1. Electrical Engineering Fundamentals, V. Del Toro, Prentice Hall of India, (2004).
2. Basic Electrical Engineering, K. Nagsarkar and M. S. Sukhija, Oxford University Press, (2005).

Reference Books:

1. Basic Electrical Engineering, D C Kulshreshtha, Tata McGraw Hill Revised First Edition.
2. Principles of Electrical Engineering & Electronics, V. K. Mehta, Rohit Mehta, S Chand Publications.
3. Basic Electrical Engineering, D P Kothari and I J Nagrath, Tata McGraw Hill, 2017
4. Power Generation, Operation, and Control by Allen J. Wood and Bruce F. Wollenberg, John Wiley & Sons, 2003.
5. Power System Control and Stability by P. M. Anderson and A. A. Fouad, Wiley-IEEE Press, 2002.
6. Electric Energy Systems Theory: An Introduction by Olle I Elgerad, T M H Edition, 1982.

DGET518: NANOMATERIALS: PROPERTIES, SYNTHESIS, CHARACTERIZATION AND APPLICATIONS

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course outcome:

- After studying this subject, students would be able to understand the nanomaterial's basics, synthesis, and characterizations
- Ability to modify or functionalize the surfaces of nanomaterials
- The student can design and fabricate the devices based on nanomaterials
- The student can perform testing of nanomaterials and apply for green energy applications

Unit I: Properties at Nanomaterials [9]

Comparison of properties at bulk and Nano, Nanomaterials, Nanostructures, chemical and physical properties-surface-to-volume ratio, the 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 [9]

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, micelles, and microemulsions, Thermolysis, Chemical vapor deposition methods, Electrochemical synthesis, Chemical modification of nanomaterials, Functionalization.

Unit III: Green Synthesis of Nanomaterials [9]

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 [9]

Powder XRD and crystallite size, Light scattering and particle size, Surface area and porosity, UV and IR studies, XPS, Raman, FTIR. Microscopy techniques, Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Scanning tunneling microscopy (STM) , Atomic force microscopy (AFM) Principle and analysis.

Unit V: Applications of Nanomaterials and Societal Implications [9]

Nanomaterials and Nanotechnology General Applications, Green technology and green energy applications, Industrial manufacturing, materials and products, and clean environment, Implications for philosophy, ethics, and society.

Text Books:

1. Charles P. Poole, Frank J. Owens, Introduction to Nanotechnology, A John Wiley & Sons, inc.
2. Pradeep T., Nano:The Essentials: Understanding Nanoscience and Nanotechnology, Tata McGraw-Hill Publishing Company Limited, New Delhi,2008.

Reference Books:

1. Rao C.N.R, Müller, Cheetham, The Chemistry of Nanomaterials, Vol 1 and 2, Wiley-VCH VerlagGmBH& Co., Weinheim, 2004.
2. Nanotechnology: assessment and perspectives, H. Brune et al., New York, Springer, 2006.
3. Nano-hype: the truth behind the nanotechnology buzz, David M. Berube; Amherst, N.Y., Prometheus Books, 2006.
4. Edelstin A.S. and CammarataR.C..Nanomaterials: Synthesis, Properties and applications, Institute of Physics Publishing 1996.
5. M.C. Roco and W.S Bainbridge, Nanotechnology: Societal Implications II – individual Perspectives, Springer publishers, sponsored by National Science Foundation, Netherlands.

DGET 510: ENERGY LABORATORY – I

(Hard-core Course) **L T P C: 0 2 4 3** **90L**

A. Course Outline:

- Basic concepts: Terminology used in experimental methods i.e. sensitivity, accuracy, uncertainty, calibration, and standards; experimental system design and arrangement.
- Analysis of experimental data: Analysis of causes and types of experimental errors, uncertainty and statistical analysis of experimental data.
- Data acquisition and processing: Data acquisition methods, data storage, and display, examples of application in typical energy system.
- Apparatus design and construction: Conceptual, substantive and detailed designs of experiments;

illustration of thermal energy equipment/devices and their accessories.

- Experiment plan and execution: Preparatory work for carrying out experiments; range of experimental study, choice of measuring instruments, measurement system calibration, data sheets and log books, experimental procedure, etc; applications.
- Technical Communication: Report preparation of experimental work, use of graphs, figures, tables, software and hardware aids for technical communication.

B. Laboratory:

S. No.	List of Experiments*
1	Measurement of global solar irradiance by using a Pyranometer.
2	To measure the efficiency of flat plate solar water heater.
3	To estimate the efficiency of the evacuated tube solar water heater.
4	To study the thermal performance of solar air heaters under natural convection.
5	To find out the efficiency of forced circulation solar air heater at a particular mass flow rate.
6	Simulation of diode characteristics.
7	Modeling and analysis of the solar cell.
8	Modeling and simulation of PV module.
9	Simulation of the DC-AC inverter.
10	Modeling and Simulation of DC-DC converter (buck and boost).
11	Simulation of standalone PV system.
12	Modeling of grid-connected PV system.
13	Modeling and Simulation of solar position using Sandia model.
14	Analysis of solar radiation using Sandia model simulation.
15	Simulation of I-V performance under clear sky (Sandia model).
16	Simulation of a solar inverter (Sandia model).
17	Application of CFD in the solar energy system.
18	Determination of flash and fire point of the given sample fuel/oil by using the Pensky Martin apparatus.
19	Characterization of Energy Materials using XRD, Microscope, FT-IR, and Raman.
20	Culture of microorganism: Media preparation.
21	Biomass harvest by various methods – a comparative study.
22	Extraction and quantification of photosynthetic pigments and biochemical components.
23	Extraction of bio-oil - chemical and physical methods and its characterization.

***Minimum of 15 practicals shall be offered**

Manuals:

1. Garg H.P., Kandpal T.C., Laboratory Manual on Solar Thermal Experiments, Narossa Publishing House, New Delhi, 1999.
2. Holman, Jack P. (1984) Experimental Methods for Engineers, McGraw-Hill Book Company.
3. Doebelin, Ernest O. (1995) Engineering Experimentation – Planning, Execution, Reporting, McGraw-Hill,

References:

1. Polak, P. (1979) Systematic Errors in Engineering Experiments, Macmillan Press Ltd.
2. Annual Book of ASTM standards, Section I – V, Vol. 05.01-05.05, 2002-2003.
3. Experiments with renewable energy-students guide- ISBN 1-928982-22-0
4. African journal of Biotechnology,vol 9(12), pp 1719 (2010)

SEMESTER-II

DGET 521: SOLAR PHOTOVOLTAIC ENERGY CONVERSION

L T P C

(Hard Core Course) **3 1 0 3 45L**

Course outcome:

- This course highlights about the solar energy, solar energy conversion principles, fundamentals about semiconductors and their application for solar cell fabrication and solar characterization
- Students will have complete understanding about the solar energy and their conversion principles – solar cell fundamentals – solar cell fabrication and characterization techniques.

Unit I: Properties of Semiconductor [9]

Semiconductors - crystals structures, atomic bonding, energy band diagram – e-k diagram, direct & indirect bandgap- p & n doping and carrier concentration - Hall Effect in semiconductors – Intrinsic & extrinsic semiconductor - compound semiconductors - diffusion and drift of carriers, continuity equation – optical absorption – carrier recombination -Effect of temperature.

Unit II: Semiconductors for Solar Cell [9]

Silicon: preparation of metallurgical, electronic and solar grade Silicon - Production of single crystal Silicon: Czokralski (CZ) and Float Zone (FZ) method – imperfections – carrier doping and lifetime - Germanium - compound semiconductors: growth & characterization - amorphous materials – Transparent conducting oxides-Anti-reflection principles and coatings – organic materials.

Unit III: Device fabrication [9]

Semiconductor junctions: Schottky barriers, MIS, P-N junction, p-i-n junction and its properties Homo & hetero junction solar cells, multi junction 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 metalization.

Unit IV: Characterization and Analysis [9]

Device isolation & analysis - 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, internal Quantum yield measurements – Effects of series and parallel resistance and Temperature - Loss analysis.

Unit V: Thermo-photovoltaics [9]

Thermo photovoltaic principles - thermophotovoltaic materials and device fabrication – thermophotovoltaic device characterization and analysis – Thermo-photovoltaic power systems.

Text Books:

1. Seminconductors for solar cells, H. J. Moller, Artech House Inc, MA, USA, 1993.
2. Fundamentals of Solar Cells: PV Solar Energy Conversion, Alan L Fahrenbruch and Richard H Bube , Academic Press, New York , 1983

Reference Books:

1. Solar Cells: Operating principles, Technology and Systems Applications, Martin Green, UNSW, Australia, 1997.
2. Solar Cells and their Applications, Larry D Partain (ed.), John Wiley and Sons, Inc, New York, 1995.
3. J. Nelson, The physics of solar cells, Imperial College Press, 2006.
4. Photovoltaic Materials, Richard H Bube, Imperial College Press, 1998
5. Practical Photo voltaics: Electricity from Solar Cells, by Richard Komp, ISBN:9780937948118, Publisher: Aatec Publications, Publication Date:February 2002.
6. Bauer, Thomas, "Thermophotovoltaics: Basic Principles and Critical Aspects of System Design" Springer (2012).

DGET 522: ELECTROCHEMICAL ENERGY CONVERSION AND STORAGE

L T P C

(Hard Core Course) **3 1 0 3 45L**

Course Outcome:

- Enrich knowledge on basics of energy conversion & storage
- Gain know-how battery and fuel cell functioning
- Gain knowledge on fabrication technology of battery and fuel cells
- Aware about the storage of renewable energy using battery

Unit I: Introduction [9]

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 [9]

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

Unit III: Secondary Batteries [9]

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

Unit IV: Supercapacitors [9]

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 [9]

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.

Text 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.

Reference Books:

1. A.J. Bard & L.R. Faulkner, Electrochemical Methods Fundamentals and Applications, John Wiley & Sons. 2nd Edition, 2001.
2. B.E. Conway, Electrochemical supercapacitors: scientific fundamentals and technological applications, Kluwer Academic / Plenum publishers, New York, 1999.
3. T.R. Crompton, Batteries reference book, Newners, 3rd Edition, 2002.
4. P. Elumalai & T. Maiyalagan, Reachable lithium-ion batteries: Trends and Trends and Progress in Electric Vehicle Technology, CRC Press, ISBN 9781138484092.

DGET 523: WIND ENERGY TECHNOLOGY

(Hard Core Course) **L T P C**

3 1 0 3 45L

Course Outcome:

- Understanding the fundamentals of wind energy technology
- Able to design and analyze the existing and innovative blade profile
- Able to assess the performance of the wind turbine
- Understanding about the selection of sites and installation of turbines

Unit I: Fundamentals of Wind Energy [9]

Nature of atmospheric winds- Wind resource characteristics and assessment– Anemometry, speed frequency distribution, effect of height, wind rose, Weibull distribution, atmospheric turbulence, gust wind speed, effect of topography. Influence of Reynolds’s number, actuator disc, Betz coefficient.

Unit II: Conceptual and Component Design [9]

Classification of wind turbines, Rotor Diameter, Machine Rating, Rotational Speed, Blades, Power Control, Pitch Bearings, Rotor Hub, Gearbox, Generator, Mechanical Brake, Yaw Drive, Tower, Foundations. Tip Speed Ratio (TSR), Choice of the Number of Blades, Relationship of TSR and Coefficient of Performance (Cp), TSR in Field Conditions

Unit III: Mechanics & Dynamics [9]

Review of Fluid Flow Concepts, Airfoil terminology, Blade element theory, Blade design, General Principles Primer (stress, strain, vibrations), Rotor Dynamics, Sources of loads, Types of loads, Aero Servo Elasticity in Wind Turbines. Primer on Fatigue, Fatigue in Wind Systems

Unit IV: Wind Turbine Performance [9]

Power v/s Energy, Power Contained in Wind, Effective Useable Energy from Wind Turbine, Practical Limits of Energy Output, Net Power Output from the Turbine, Important Rules for Wind Turbines,

Power Curve, Wind-turbine Performance Measurement, Aerodynamic Performance Assessment, Dynamics, Estimation of Energy Capture, and The Performance Curves.

Unit V: Wind Farm and Wind Energy Economics [9]

Onshore, offshore wind energy, wind farms, design of wind farms, Project Development, Visual and Landscape Assessment, Noise, Electromagnetic Interference, Ecological Assessment, Finance Engineering Economics Basics, Wind Turbine Cost Analysis,

Text Books:

1. Steve Parker, "Wind power", Gareth Stevens Publishing, 2004.
2. Freris L.L., Wind Energy Conversion Systems, Prentice Hall 1990.

Reference Books:

1. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, ASME Press, NY 1994

DGET 524: BIOPROCESS ENGINEERING FOR BIOFUELS

(Hard Core Course) **L T P C**

3 1 0 3 45L

Course outcome:

- After studying this subject, students would be able to measure the extent of biochemical growth types of biochemical interactions for living processes.
- Ability to analyze the microbial growth kinetics
- The student can design a fermenter for the bioprocessing of different products.
- The student can scale up the bioprocess for large scale production
- The students can monitor the bioprocess for higher production efficiency

Unit I: Engineering Biology [9]

Overview of bioprocess engineering, Biological systems, Cellular components and cell growth, Bioenergetics and cellular metabolism, Metabolic pathways, Autotrophic metabolism, Anaerobic metabolism, Metabolism of hydrocarbons, Biosynthesis.

Unit II: Enzyme Kinetic [9]

Enzymes and its function, Enzyme synthesis, Mechanism of enzymatic action, Enzyme kinetics, Single enzyme kinetics, Michaelis–Menten kinetics, Model of complex enzyme kinetics, Immobilized enzyme systems, Enzymatic processes

Unit III: Cellular growth [9]

Building blocks of cellular components, Cellular growth and models, Growth curves, Kinetic of cell growth, Batch growth kinetics, Continuous growth kinetics, Determination of growth parameters, Stoichiometry of microbial growth, Yield coefficients for cell mass

Unit IV: Reactor design [9]

Principles of bioprocess, Batch, fed-batch, and continuous processes Chemostat systems, Operation and performance of the process systems, Types of bioreactors in bioprocesse, Instrumentation and control of bioreactors, Reactor design considerations, Scale-up and scale-down of bioprocesses, Immobilized cell system, Passive and active immobilization, Solid-state fermentation

Unit V: Bioprocess Applications and Product Recovery [9]

Anaerobic bioprocessing, Cellulosic ethanol production, Biological production of 2-butanol, Lactic acid production, Aerobic fermentation, Renewable chemicals production, Product separation process, Cell disruption and mechanical separation, Filtration, Centrifugation, Coagulation, Flocculation, Separation of soluble products, Biosafety and Bioethics

Text Books:

1. Bailey, J. E., & Ollis, D. F. (2018). Biochemical engineering fundamentals. McGraw-Hill.
2. Shuler, M. L., & Kargi, F., (2006). Bioprocess Engineering Basic Concept Pearson Education, Inc.

References:

1. Cornish-Bowden, A. (2013). Fundamentals of enzyme kinetics. John Wiley & Sons.
2. Liu, S. (2020). Bioprocess engineering: kinetics, sustainability, and reactor design. Elsevier.
3. Doble, M., Kruthiventi, A. K., & Gaikar, V. G. (2004). Biotransformation and bioprocesses. CRC Press.

DGET525: SOLAR THERMAL DEVICES AND THERMAL ENERGY STORAGE

(Hard Core Course) **L T P C**
3 0 0 3 45L

Course Outcome:

- To provide understanding about application of various low temperature solar thermal devices
- To study the importance of solar collectors for high temperature applications
- To give a detailed understanding on thermal energy storage and storage materials
- An extensive analysis on standard methods of testing of solar thermal collectors
- To gain knowledge on making economic analysis on solar thermal energy projects

Unit I: Low Temperature Solar Thermal Energy Systems [10]

Solar water heater- Flate plate type; Evacuated tube solar water heaters; Solar air heating systems: Description and classifications; Solar drying: Designing of solar drier; psychrometric chart; Energy balance equation. Solar distillation: Working principle; thermal efficiency; various designs of solar still. Solar pond: Description; Non-convective solar pond; Operational problems; Solar cookers-box type: Types of solar cookers; First figure of merit and second figure of merit; Solar refrigeration and air conditioning: Principle of absorption cooling; Lithium bromide-water absorption system; Vapor compression refrigeration.

Unit II: Medium and High Temperature Solar Thermal Energy Systems [8]

Solar concentrating systems: Types of concentrators, single axis and two axis tracking; Solar energy for industrial process heat: Hot water, hot air and steam based industrial process heat systems; Solar thermal power generation: Principles of solar engines; Solar thermal power plants: Parabolic trough, central receiver, parabolic dish, compact Fresnel linear reflector technology.

Unit III: Solar Thermal Energy Storage [16]

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; 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: Testing of Solar thermal collectors [5]

Authorized testing protocols for solar water heater (flat plate type), Evacuated solar water heater, Solar box cooker, Solar air heater, Solar concentrating cooker, and solar concentrator for high temperature applications.

Unit V: Economic analysis for solar thermal engineering projects [6]

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.

Text Books:

1. Duffle and Beckman, Solar Thermal Engineering Process, John Wiley & Sons, New York
2. N.C. Harris, C.E. Miller and I.E. Thomas, Solar Energy Systems Design, John Wiley & Sons, New York

Reference Books:

1. P.J. Lunde, Solar Thermal Engineering, John Wiley & Sons, New York
2. S.P. Sukhatme, Solar Energy, Tata McGrew Hill Company Ltd., New Delhi
3. F. Kreith and J.F. Kreider, Principles of Solar Engineering, Hemisphere Publishing Coro.
4. Hafiz Muhammad Ali; Furqan Jamil; Hamza Babar, Thermal Energy Storage: Storage Techniques, Advanced Materials, Thermophysical Properties and Applications, Springer, Singapore.
5. G. Beghi, Thermal Energy Storage, Springer, 2012.
6. Garg H P., Prakash J., Solar Energy: Fundamentals & Applications, Tata McGraw Hill, New Delhi, 1997

DGET 526: GREEN BUILDING AND SUSTAINABLE DEVELOPMENT

(Hard Core Course) **L T P C**
3 1 0 3 45L

Course Outcome:

At the end of the course, the student will be able to

- Understand the concepts and factors influencing green building concepts, systems and energy management.
- Impact of indoor environmental quality on occupant well-being and comfort.
- Identify and compare existing energy codes, green building codes and green rating systems.

- Study about the fundamentals of energy and energy production systems pertaining to Residential, Commercial, Institutional and Public Buildings.
- Demonstrate the energy management of electrical equipment and appliances in buildings
- Use low embodied energy industrial and building materials and cost effective building technologies

Unit I: Introduction [8]

Conservation of Energy, Energy Utilization in Buildings, Sustainable construction, Need of energy in buildings, Study of climate and its influence in building design for energy requirement, Principles of energy conscious design of buildings, typical features of green buildings, benefits of green buildings towards sustainable development, Environment and Resource concerned of building, Implementation strategies related to Integrative design Strategies.

Unit II: Implications of Building Technologies Embodied Energy of Buildings [7]

Primary and Secondary Energy, Embodied Energy, Role of Materials, Emission and pollution, Resources for Building Materials, Life Cycle Assessment, Life Cycle Costing, Key considerations regarding sustainable materials, High-Performance Building Energy Design Strategy and Goal Settings Methods to reduce embodied energy in building materials, Energy efficiency in a green building.

Unit III: Comforts in Building [10]

Thermal comfort in Buildings – Issues, Passive Cooling concepts, Heat transfer, Characteristic of Building Materials and Building Techniques, Properties of Atmospheric air, Psychometric properties of Air, Chart, Analyzing Air-conditioning Processes; Heating, Cooling, Dehumidification and Humidification, Evaporative Cooling, Adiabatic mixing of two moist air streams, Cooling towers, energy efficient appliances for heating and air conditioning systems.

Unit IV: Alternative Building Materials [10]

Fibers- metal and synthetic - Properties and applications. Fiber reinforced plastics, Matrix materials, Fibers organic and synthetic - Properties and applications. Building materials from agro and industrial wastes, construction and demolition wastes and mine wastes.

Unit V: Green Composites for buildings and ratings [8]

Concepts of Green Composites. Water utilization in Buildings, Low Energy approaches to Water Management. Urban Environment and Green Buildings. Green Cover and Built Environment. Rating systems for energy efficient buildings in India and other countries. Green building rating systems and certification such as LEED, GRIHA, ASOOCHAM GEM, BEE and ECBC.

Text Books:

1. K.S.Jagadish, B. U. Venkataramareddy, K. S. Nanjundarao. Alternative Building Materials andTechnologies. New Age International, 2007.
2. Low Energy Cooling For Sustainable Buildings. John Wiley and Sons Ltd, 2009.

Reference Books:

1. Green My Home!: 10 Steps to Lowering Energy Costs and Reducing Your Carbon Footprint, by Dennis C. Brewer, ISBN:9781427798411, Publisher: Kaplan Publishing, Publication Date: October 2008. C. Givoni, Man, Climate and Architecture Elsevier, 1969.
2. T. A. Markus and E. N. Morris Buildings Climate and Energy. Pitman, London, 1980. Arvind Kishan et al (Ed.)

3. Sustainable Building Design Manual. Vol 1 and 2, Teri, New Delhi, 2004. Hill, 2001.
4. Osman Attmann Green Architecture Advanced Technologies and Materials. McGraw Hill, 2010. 8. Michael F. Ashby Materials and the Environment, Elsevier, 2009. 9. Jerry Yudelson Green Building Through Integrated Design. McGraw Hill, 2009.

DGETY 527: SOLID WASTE MANAGEMENT TO ENERGY CONVERSION

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course outcomes:

- Explain the basics of municipal waste and waste management challenges.
- To learn the waste treatment and disposal techniques/methods such as recycling, composting, landfills, and briquetting.
- Imparting in-depth knowledge of thermochemical and biochemical waste to energy techniques (WtE). In addition, it deals with environmental effects due to various WtE conversions and analyses case studies for WtE potential and challenges.
- To facilitate students to develop skills in integrated WtE management systems.

Unit I: Introduction to waste & waste processing [9]

Definitions, sources, types municipal solid waste (MSW), agro waste, forest waste, biomedical waste (BMW) and composition of various types of wastes. Characterization of municipal solid waste (MSW) and calorific values, fundamental elements and factors effecting MSW composition, waste stream assessment, waste collection and transportation, transfer station, waste processing-size reduction, separation; waste management hierarchy, waste minimization and recycling of MSW; life cycle analysis (LCA), material recovery facilities (MRF), 6Rs of recycling, recycling of paper, glass, plastics, ferrous and non-ferrous metals.

Unit II: Waste Treatment and disposal [9]

Composting- basics, types, aerobic, anaerobic and vermin-composting, essential elements of composting. Landfills for waste, types, typical landfill process, methods and sitting consideration, layout and preliminary design of landfills. Sanitary and Bio-reactor landfills, composition, characteristics, generation, movement and control of landfill leachate and gases, environmental monitoring system for land fill gases. Briquetting, utilization and advantages of briquetting

Unit III: Thermo-chemical conversion process for waste to energy [9]

Thermo-chemical process: Incineration, gasification, pyrolysis and its types, plasma arc technology, Hydrothermal Gasification, Liquefaction and Carbonization and advanced processes, -environmental and health impacts of incineration, dioxins and its impact on health, pollution control devices, waste heat recovery, strategies for reducing environmental impacts. Gasification: syngas utilization via F-T syntheses for fuels, plastic to bio-oil *via* pyrolysis.

Unit IV: Bio-chemical Conversion process for waste to energy [9]

Anaerobic digestion of sewage and municipal waste to biogas production, typical process, types of bio-digesters, and purification of bio-gas. Organic waste to biodiesel via transesterification, fermentation for bio-alcohols, bio-hydrogen and its processes. Bio-hydrogen processes: direct/indirect photolysis, photo fermentation, and microbial electrolysis-cell. Integration of bio-chemical conversion processes.

Unit V: Environmental and health impacts-case studies [9]

Integrating waste management system, present status of technologies for conversion of waste into energy, design of waste to energy plants for cities, small townships and villages. Environmental and health impacts of waste to energy conversion. Carbon credits: carbon footprint calculations. Case studies of commercial waste to energy plants- success and failure, waste to energy- potentials and constraints in India, eco-technological alternatives for waste to energy conversions - Rules related to the handling, treatment and disposal of MSW and BMW in India.

Text Books:

1. Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable omparisons, by Gary C. Young, ISBN:9780470539675, Publisher: John Wiley & Sons, Publication Date: June 2010.
2. Waste-to-Energy. Technologies and Project Implementation by Marc J. Rogoff And Francois Screve (Auth.)Publisher:William Andrew, 2011/2019

References:

1. Waste to Energy (WTE) Conversion Technology by Klinghoffer, N. B. (Hrsg.), Castaldi, M. J. (Hrsg.). ISBN 13:9780857090119 Woodhead Publishing Ltd, 2013.
2. Recovering Energy from Waste Various Aspects Editors: Velma I. Grover and Vaneeta Grover, ISBN 978-1-57808-200-1; 2002.
3. Sustainable food waste-to-energy systems by Babbitt, Callie W., Trabold, Thomas, ISBN 13:9780128111581,Publisher:Academic Press, 2018.
4. Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Prentice Hall, 2000.
5. Advances in Waste-to-Energy Technologies by Rajeev Pratap Singh (Editor), Vishal Prasad (Editor), BarkhaVaish (Editor), ISBN 10:1138390429, CRC Publishing, 2019.
6. Waste-to-Energy, Second Edition: Technologies and Project Implementation by Marc J. Rogoff, Francois Screve, Publisher:William Andrew, 2011.

DGET 528: NANOTECHNOLOGY FOR SOLAR ENERGY SYSTEMS

(Soft Core Course) **L T P C**
3 0 0 3 45L

Course outcomes:

- This course helps students to learn Nano electronics and Physical properties of Nano systems
- Learners are immersed in discussions about green energy technologies, Challenges in energy conversion, role of nanostructures & materials and the impact of sustainability on society, energy consumption.
- To learn students exposed to Nanotechnology for energy storage and energy efficient devices

Unit I: Nano-electronics [9]

Concept of wave-matter duality, phase and group velocities, electron state in solids, uncertainty principle, operators, quantum mechanical postulates, Schrödinger’s Wave Equation, free electron gas, spherical, electron in spherical potential (hydrogen atom), Hydrogen molecule, Atom by Atom arrangements, band structure formation, E-k diagram, electronic states of 2-D, 1-D, 0-D nanosystems.

Unit II: Physical Properties of Nanosystems [9]

Light absorption in Nano systems, size dependence and material dependence of absorption, band gap engineering, Fermi-level, ballistic and diffusive transport in nanosystems, coulomb blockade, resonant tunnelling, carrier separation techniques

Unit III: Nanotechnology for Solar Energy Conversion [9]
Challenges in energy conversion – role of nanostructures & materials – nanomaterials in solar Photovoltaic Technology: quantum well solar cell, quantum wire solar cell, quantum dot solar cell – quantum dot sensitized solar cell, photo-current calculation. Tandem structures –nanotechnology for solar thermal fuels, nanotubes for solar energy harvesting, Concept of photo-electro chemical cell.

Unit IV: Nanotechnology for energy storage [9]
Nanostructured electrodes fabrication, nanotubes for energy storage, electrochemical storage, Conversion of solar energy to hydrogen.

Unit V: Nanotechnology for energy efficient devices [9]
Energy efficient devices –fabrication and applications of quantum well LED as light device, – optical amplifiers, quantum well lasers, optical switch, Quantum dot luminescence materials.

Text books:

1. Physical principles of micro Micro-electronics, G.Yepifanov, Mir Publishers
2. Semiconductor device-basic principles-Jasprit singh, Wiley

References:

1. Quantum Chemistry, Levine, Prentice Hall
2. Statistical Mechanics and properties of matter, E.S.R Gopal,Ellis Horwood
3. Introduction to solids, Azaroff, Tat Mc-Graw Hill.

DGET529: CARBON SEQUESTRATION AT THE LANDSCAPE LEVEL

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

- Learn the concept of CO2 generation and fixation in the globe.
- Familiarize the international laws, convention and regulation on carbon sequestration
- Develop basic understanding on biomass synthesis, available energy potential, its exploitation, current scenario in India.
- Develop basic understanding on available technological options for CO_2 sequestration

Unit I: Climate change and International agreements [8]
The green-house effect. The United Nations Framework Convention on Climate Change (UNFCCC). The Intergovernmental Panel on climate change (IPCC), the Kyoto Protocol, the Clean Development Mechanism (CDM). Afforestation and Reforestation projects, Reduced Emissions from Deforestation and Degradation (REDD). CDM projects, finance, project development. Conservation of natural carbon sinks. National inventory management system in India (NIMS)

Unit II: Primary productivity: mechanisms and assessment [10]
Photosynthesis, absorption and yield. C3, C4 and CAM pathways. Laboratory measurement of primary productivity: cell, plant, ecosystem. Direct field measurements of biomass and primary productivity: allometric models, harvest methods for forests, grasslands and ocean. Indirect measurements of biomass and primary productivity: remote sensing and other methods. The CDM methodologies for measurement of stocks and fluxes.

Unit III: Biogeochemistry [9]

Role of soil in the carbon balance: decomposition and sequestration in soils. The carbon cycle: plant, soil and atmosphere. Impact of soil degradation. Conditions for the formation of fossil stocks of carbon. Carbon balance of ecosystems: forests, grasslands and oceans. Impact on the global carbon balance. Soil Organic Carbon (SOC) and biodiversity and climate change. SOC global stock – hot spots and bright spots. Measurement, reporting and verification of SOC. SOC for sustainable development.

Unit IV: Remote sensing and spatial analysis [10]

Sensors. Reflectance of vegetation. Measuring biomass with remotely sensed data. Measuring primary productivity with remotely sensed data. High resolution satellites, use and limitations to measure biomass and primary productivity. Low resolution satellites use and limitations to measure biomass and primary productivity. Regional and global assessments of biomass and primary productivity. Introduction to Geographic Information Systems (GIS). Land-use and land-use changes assessment. The Clean Development Mechanism (CDM) methodologies for measurement of stocks and fluxes at the landscape level.

Unit V: Carbon Sequestration Technologies [8]

Post, Pre and Oxy combustion capture – Sequestration in geological formation: Oil-Gas, Deep sea and unmineable coal seams. CCS programmes, issues and challenges. Clean Technology Scenario and CCS. CCS an international policy strategy and legal perspective.

Text Books:

1. Bhatta, B. 2009. Remote sensing and GIS. Oxford UniversityPress.
2. Monteith, J. L., and M. H. Unsworth. 1990. Principles of environmental physics, Second edition. EdwardArnold.

References:

1. Neteler, M., and H. Mitasova. 2008. Open Source GIS. A GRASS GIS approach, Third edition.Springer.
2. Pachauri, S. and L. Jiang, 2008. The household energy transition in India and China. Interim Report, International Institute for Applied SystemsAnalysis.
3. Walker, B. and W. Steffen (eds.) 1996. Global change and terrestrial ecosystems. International geosphere-biosphere programme book series. Cambridge University Press.
4. Lefèvre Clara, Rekik Fatma, Alcantara Viridiana, Wiese Liesl, (2017), Soil Organic Carbon, the hidden potential. Food and Agriculture Organization of the United Nations.
5. A policy document on 'Exploring the clean energy pathways, the role of CO_2 storage' Published by International Energy Agency, July 2019. www.iea.org .
6. CRS report by Peter Fogler on 'Carbon capture and sequestration', June 2009.

DGET530: MICROBIAL TECHNOLOGY FOR BIOFUEL PRODUCTION

(Soft-core Course) **L T P C**
3 0 0 3 45L

Course outcome:

- Attain knowledge on fundamental of Microbial resources for biofuels production
- Acquire insight about the value added products of microbial resources
- Understanding the tools and advancement in microbial engineering
- Acquisition of skill on fermentation technology of biofuels

Unit I: Microbial resource [9]

Significance of microbes, Microbes from different source: soil, water, air, food, waste, degraded materials, heterotrophic, autotrophic, characterization of microbes, classification, identification of microorganisms: morphology, biochemical, molecular, cultivation, reproduction and growth, pure culture, contamination, bacteria, fungi, actinomycetes, algae, etc.

Unit II: Value added products from Microbes [9]

Enzyme production, Microbes for enzymatic deconstruction of biomass: cellulase, β-glucosidase, xylanase, ligninolytic enzymes, Microbial fermentation to biofuels: ethanol, butanol, hydrogen, methane, biooil.

Unit III: Biochemical processes [9]

Terrestrial bioresource, marine bioresource, C3 and C4 energy plants, microbial resource, proximate analysis of biomass: Cellulose, Hemicellulose, Lignin, Protein, pretreatment process: physical, chemical, biological, hydrolysis, enzyme production: solid state, submerged fermentation, downstream processing, enzyme activity.

Unit VI: Microbial Engineering Technology [9]

Generation of biofuels production, Microbial genetics, Synthetic microbiology, development of industrial strain, tools in microbial engineering, Genetically Modified microbes for biofuel production.

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Unit V: Fermentation Technology for Biofuel [9]

Fermentation process, fermenter, types of fermenter, hybrid fermenter, sterilization, fermentation media, precursor and inhibitors, buffers, types of fermentation, upstream process, downstream process, troubleshooting mechanism.

Text books:

1. Ivanov, V. (2020). Environmental Microbiology for Engineers (3rd ed.). CRC Press. https://doi.org/10.1201/9780429317156
2. Handbook of Research on Bioenergy and Biomaterials, Consolidated and Green Processes, ISBN:9781000210736, 1000210731, Apple Academic Press, 2021

Reference books:

1. Advances in Biofuels and Bioenergy, ISBN:9781789232868, 1789232864, Intech Open, Editors:Jaya Soneji, Madhugiri Nageswara-Rao, 2018
2. Varma, A., Kumara Behera, B. (2017). Microbial Biomass Process Technologies and Management Germany: Springer International Publishing, ISBN:9783319539133, 3319539132.
3. Microbial Resources for Sustainable Energy, Basanta Kumara Behera, Ajit Varma, Springer, 2016, ISBN 3319337785, 9783319337784.

DGET531: GREEN CHEMICAL TECHNOLOGIES

(Soft Core Course) **L T P C**

3 0 0 3 45L

Course Outcome:

- Understand the principles of green chemistry and engineering
- To become conscious of sustainability and environmental viability.

- Awareness of emerging catalytic chemical technologies
- Access to an expanding range of new green technologies and strategies

Unit I. Types of waste, waste minimization and recycling. [9]

Conventional chemical synthesis and environmental impact – generation of wastes and pollution - sources of waste, different types of waste, chemical, physical and biochemical methods of waste minimization and recycling. Pollution – types, causes, effects and abatement. Hazard identification, assessment and safety aspects at process development and design stage. Need for environmental mitigation and energy efficient processes.

Unit II. Green chemical technologies, metrics, Concept of energy and analysis [9]

Green chemical technologies – Concepts of Green Chemistry and green engineering with examples. Environmentally benign processes- alternate solvents- supercritical solvents, ionic liquids, water as a reaction medium. Green chemistry metrics- atom economy, E factor, reaction mass efficiency and other green chemistry metrics, application of green metrics analysis to synthetic plans. Concept of energy and analysis. Energy system analysis, Energy efficient design of processes, Energy Policy and Management

Unit III. Catalysis in green synthesis [9]

Catalysis in green synthesis: TON, TOF, energetic of catalysis. Catalysis using solid acids and bases: Zeolites, mesoporous materials and clays as catalysts, shape selectivity. catalysis by metals, metal oxides. application in bulk and fine chemical synthesis chemicals, environmental applications. Phase Transfer catalysis – basic concepts in phase transfer catalysis- basic steps in PTC. Single-atom catalysis.

Unit IV. Catalytic technologies - principles, synthesis, advantages and applications [9]

Photo catalysis - principles, synthesis, advantages and applications. Conventional Batch and Continuous-Flow Chemistry. Reactor Concepts for Flow Photochemistry. Electrocatalytic synthesis, photo electrochemistry and other environmentally benign and cost-effective integrated approaches.

Unit V. Green processes, concepts and design: Life cycle analysis [9]

Designing green processes- safe design, process intensification, in process monitoring. Life cycle analysis. Safe product and process design – Design for degradation, Real-time Analysis for pollution prevention, inherently safer chemistry for accident prevention. Case studies

Text books:

1. Green Chemistry – An introductory text - M. Lancaster, RSC
2. Environmental chemistry - Stanley E Manahan, Lewis Publishers

Reference books:

1. Catalysis- concepts and green applications- Gadi Rothenberg-Wiley VCH, 2017.
2. Visible Light Photocatalysis in Organic Chemistry- Corey R.J. Stephenson, Tehshik P. Yoon, David W.C. MacMillan, Wiley, ISBN: 978-3-527-33560-2; 2018.
3. Sustainable Flow Chemistry: Methods and Applications- Luigi Vaccaro- Wiley, 2017.

DGET 520: ENERGY LABORATORY – II

L T P C

(Hard Core Course) **0 2 4 3 90L**

List of Experiments

S. No.	List of Experiments*
1	Study I-V Characteristics of Si-based Solar module
2	Effect of Solar Irradiance/ Inclination on the I-V Characteristics of a given Si-based Solar Module
3	Compare TWO given Solar Modules of Varied Specification (Si-based with thin-film modules)
4	Study of Solar Module I-V Characteristics with Series and Parallel Connection
5	Hand on-training on 500 W or 1 kW PV plant on-grid
6	Solar PV array design using bypass and blocking diode
7	Design and assembly of Solar PV battery charger and battery bank charge controller
8	Design and assembly of AC-DC and DC-AC power inverter
9	Study on the solar cell to the module assembly process and out-put characteristic
10	To evaluate the performance of direct solar dryer under forced circulation
11	To evaluate the performance of solar tunnel dryer under forced circulation
12	To study the thermal performance of concentrating collector
13	To find F_1 of a solar box cooker
14	To calculate the heat efficiency factor for solar cooker
15	Performance analysis of PEM fuel cell using battery/solar cell
16	Performance analysis of PEM fuel cell using solar cell
17	Evaluate Charge-discharge Characteristics of a Secondary Battery
18	Determination of Free Fatty Acid and Iodine Value
19	Quantitative analysis of cellulose (Filter paper assay) by spectrophotometer
20	Biomass briquetting with pure and blended agricultural residues
21	Monoculture of algae by streak-plate method and biomass growth curve study
22	Isolation of hydrolytic bacteria from biodegradable sources by serial dilution technique
23	Microbial production of Hydrogen
24	Microbial production of bioethanol
25	Anaerobic digestion of biomass for biogas production

***Minimum of 15 practical shall be offered**

Manuals:

1. Garg H.P., Kandpal T.C., Laboratory Manual on Solar Thermal Experiments, Narora Publishing House, New Delhi, 1999.
2. Holman, Jack P. (1984) Experimental Methods for Engineers, McGraw-Hill Book Company. [3] Doebelin, Ernest O. (1995) Engineering Experimentation – Planning, Execution, Reporting, McGraw-Hill,

References:

1. Polak, P. (1979) Systematic Errors in Engineering Experiments, Macmillan Press Ltd.
2. Annual Book of ASTM standards, Section I – V, Vol. 05.01-05.05, 2002-2003.
3. Experiments with renewable energy-students guide- ISBN 1-928982-22-0, African Journal of Biotechnology, Vol. 9 (12), pp 1719 (2010).

SEMESTER – III

DGET611: RESEARCH METHODOLOGY & MINI-PROJECT

(Hard Core Course) **L T P C**

0 2 4 3 90L

Course Outcome:

- Through this course project work student shall get acquaintance in the selection of research problem, its analysis, carrying out relevant literature survey and reviewing. Also, they will learn how to analyse data and write a technical report.
- Students shall be imparted training on selection of research theme/problem, scientific approach, defining specific objectives, design of experiment, estimation of budget, estimation of time duration, execution, data collection, analysis & presentation and carry out experimental and/or theoretical studies.
- Students shall be exposed to classification of IPRs, identification of IPR values in the research and development work being carried out, processes of patent drafting and filing, institutional, national and international policies on IPR etc.

Unit I: Research Methodology [9]

Research, keywords, literature survey methods, research objectives, research design/plan, choosing experimental methods, data collections and analysis, Research ethics – conflict of interest issues, citation of prior art, plagiarism & permissible similarity in writing, Similarity checking tools.

Unit II: Thesis writing [9]

Components of thesis- title, abstract, introduction, objectives, methods, results, tables, figures, graphs, discussion, summary, acknowledgement, in-text citations, reference list, and appendix.

Unit III: Presenting and publishing research [9]

Focus of conferences and workshops - Oral presentation skills – Post presentation of research outcome – Abstracts & extended abstracts – Proceedings of technical deliberation - Publication in journals, conference proceedings and in book or as book chapters.

Unit IV: Research article & Research Proposals [9]

Components of research article - Title, abstract, key words, introduction, citations, introduction, objectives, methods, results, tables figures, graphs, discussion summary, and references. Instruction to authors by journal for writing a research paper. Components of proposal document- Title, aim, research background, project outline, research methodology & budgeting, time schedule, deliverables and references.

Unit V. Intellectual Property [9]

Classification of IPs - identification of IP values in research outcome – Prior art search – Open source and commercial search engines. Patents and Trade Marks - National and institutional IPR Policies – Patent filing procedures.

Text books

1. Research Methodology: Methods and Techniques, C.R. Kothari, Gaurav Garg, New Age International, 4th Edition, 2018

2. Research Methodology a step-by step guide for beginners, Ranjit Kumar, SAGE Publications Ltd, 3rd Edition, 2011

Reference books

1. Research Methods: the concise knowledge base, Trochim, Atomic Dog Publishing, 2005
2. Conducting Research Literature Reviews: From the Internet to Paper, Fink A, Sage Publications, 2009

DGET612: SOLAR PHOTOVOLTAIC POWER SYSTEMS

	L T P C	
(Soft-core Course)	**3 0 0 3**	**45L**

Course Outcome:

- This course teaches about the solar photovoltaic power system from module assembly process to establishment and commissioning of solar photovoltaic power plant
- Students are expected to understand the technologies involved in the establishment and maintenance of solar photovoltaic power plant

Unit I: Solar PV Module [9]

Introduction: module and circuit design - identical and non-identical cells - module structuring and assembly - assembly materials – environmental protection – interconnect: types and assembly process – crystalline and thin film modules - issues with solar PV modules, bypass diode and blocking diode – module testing and analysis- thermal considerations - electrical considerations and output conditioning - mechanical protection & module testing and evaluation.

Unit II: SPV Systems & Components [9]

Introduction to PV systems - system components: module and array – Charge controllers – Inverters – Batteries – power conditioning and Regulation – Mechanical assemblies – Balance of System Components

Unit III: SPV Power Systems [9]

Types of SPV power systems: MW general power systems – Grid connected power systems – Remote area power systems – Specific purpose Photovoltaic systems: Space – Marine – Telecommunication – water pumping – refrigeration etc., Concentrator solar cells and systems. Space quality solar cells and satellite power systems – Photovoltaic power system for electrical vehicles: BLDC motors: power, drives and controllers – Battery bank and charging strategies - vehicle and circuit design.

Unit IV: Power System Design and Installation [9]

Power considerations and system design – Array integration: mechanical integration – electrical integration – utility integration – Inspection and commissioning - SPV power system maintenance: cleaning, shadowing, stability etc., and troubleshooting – Economics.

Unit V: Space Power Systems [9]

Solar Photovoltaic Power systems – Thermophotovoltaic power systems - Deep space power systems: Nuclear fusion systems, Radio-isotope Thermoelectric Generator power systems - Stirling Radioisotope Generator (SRG).

Text Books:

1. Solid State electronic devices by Ben G. Streetman, Prentice-Hall of India Pvt. Ltd., New Delhi 1995.
2. Clean electricity from photovoltaics, M. D. Archer, R. Hill, Imperial College Press, 2001.

Reference books:

1. Photovoltaic Systems Engineering, Roger Messenger and Jerry Vnetre, CRC Press, 2003.
2. Generation Distribution and utilization of Electrical Energy, C.L.Wadhwa, Wiley Eastern Ltd., India(1989)
3. Electrical Power Systems Quality by Roger C.Dugan , Mark .F. Mc Granaghan, Surya Santaso, H.Wayne Beaty, Second Edition, Mc Graw Hill, 2002
4. Fundamentals of Photovoltaic Modules & Their Applications, by Gopal Nath Tiwari, SBN:9781849730204, Publisher: Royal Society of Chemistry, 2010.

DGET613: ARTIFICIAL INTELLIGENCE, MACHINE LEARNING AND DATA ANALYSIS FOR PHOTOVOLTAIC SYSTEMS

L T P C

(Soft-core Course) **3 0 0 3 45L**

Course Outcome

- The course will equip the participants for advanced technology development (R&D) with data analysis.
- Students are exposed to learn Artificial intelligence in the area of sustainable energy conversion

Unit I: Introduction to Artificial Intelligence and Machine Learnings [9]

Basic concepts of AI, linear regression, learning schemes, shallow and deep learning, Principal component analysis, t-Distributed Stochastic Neighbour Embedding (t-SNE), k-fold cross validation, classification, clustering-k-means, support vector machine, Multiple linear regression, ANN: perceptron, back propagation, CNN

Unit II: Data Representation [9]

Python for data analysis, NumPy, panda, data frame, data cleaning, data representation-Matplotlib Matlab ANN tool kit

Unit III: Sandia Model [9]

Sandia model: radiation model, radiation correction factors, PV model, inverter model, Pvlib data analysis tool kit

Unit IV: Data Analysis [9]

PV data analysis-excel sheet data, Big data analysis, data mining, missing values, normalization and standardization, split and data set, feature selection, dimension reduction, linear regression, support vector regression, mean score, mean absolute error, R^2 score

Unit V: ANN solar cell models [9]

Solar energy forecasting, ANN solar cell models, ANN based MPPT-PSO trained ANN MPPT, Fuzzy logic based MPPT

Text Books:

1. Artificial Intelligence in Energy And Renewable Energy Systems, ISBN-13: 978-1600212611,Nova Science Pub Inc

2. Introduction to Machine Learning with Python: A Guide for Data Scientists 1st Edition, Andreas C. Müller, Sarah Guido, ISBN: 9781449369415, Publisher: O'Reilly

Reference books:

1. MATLAB Deep Learning: With Machine Learning, Neural Networks and Artificial Intelligence1st ed, Phil Kim, publisher: ISBN-13: 978-1484228449, Apress

DGET614: ADVANCE POLYMERIC MATERIALS FOR RENEWABLE ENERGY SYSTEMS

(Soft-core Course) **L T P C 3 0 0 3** **45L**

Course Outcome:

Students will learn about advanced materials such as composites, polymeric and hybrid materials: synthesis, characterization, properties, fabrication techniques, and applications in renewable energy systems. The paper encourages students to explore them in synthesizing advanced materials for renewable energy conversion and storage technologies.

Unit I: Fundamentals of Polymers and Composites [9]

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

Unit II: Polymers and Composites for Solar Energy [10]

Organic versus inorganic photovoltaics: Introduction- principles of organic, inorganic, polymeric, and hybrid photovoltaics. Organic photoactive material synthesis- low bandgap conducting polymers. Donor and acceptor organic molecules, and bulk heterojunction devices with focus on organic/polymeric materials. Processing and printed plastic solar cells and hybrid tandem cells. Stability and lifetime of organic, polymeric, and metal oxide–polymer bulk heterojunction solar cells. Polymers and composites as solar thermal materials for solar thermal -polymeric solar absorbers and polymer solar reflectors. Anti-reflection and absorbing coating material for solar energy application.

Unit III: Polymers and Composites for Wind and Biomass Energy [10]

Composite material synthesis for wind energy- glass, carbon, resins, aramid fiber-reinforced polymeric composites, natural fiber reinforced polymers- biocomposites, and nanocomposites for wind turbine blades. Composite manufacturing processes- Spary lay-up, press-forming, vacuum bagging and autoclave, resin infusion-vacuum process, reactive resin transfer molding ,and others. Testing- thermal analysis, tensile test, compression test, shear testing, rheology, fatigue, and recycling strategy for sustainability. Hybrid composites catalysis in biochemical/thermochemical biomass conversion to biofuels: hydrolysis, hydro treating, reforming, deoxygenation, hydrothermal liquefaction, gasification, pyrolysis, Fischer–Tropsch synthesis, steam reforming/cracking, and transesterification. Polymeric sorbents for biogas cleaning and separation.

Unit IV: Polymers and Composites for Fuel Cells [8]

Polymer electrolyte membrane synthesis and characterization for fuel cells: Structure-property relationships, membrane electrode, organic-inorganic membranes, and composites for bipolar plates. Design and development of proton exchange membranes fuel cell (PEMFC) based on Nafion, sulfonated poly (ether-ether ketone)s, sulfonated poly(aryl ether) for PEMFC and direct methanol fuel cell (DMFCs). Polymer composite membrane role (cation/anion/proton-exchange membranes) in bioelectrochemical systems (MFCs) –construction and performance of MFCs.

Unit V: Polymers/Composites for Battery and Miscellaneous Renewable Energy [8]

Polymer and composite-based lithium polymer battery. Preparation and fabrication of solid-state electrolytes. Polymer/composite-based thermoelectric materials synthesis and fabrication. Materials for energy conversion and efficiency in buildings. Natural materials for sustainable energy systems.

Text Books:

1. Gowariker and Viswanathan, Polymer Science, Wiley Eastern, 1986.
2. Bill Meyer, A Text Book of Polymer Chemistry, John Wiley & Sons, 1994.

Reference Books:

1. Composite Materials, Author by Deborah D.L.Chung, Springer, 2002.
2. Nanostructured Conductive Polymers, Editor. Ali Eftekhari, Wiley, 2010.
3. Organic Photovoltaics, CRC press-Taylor & Francis, Edited by Sam-Shajing Sun, Niyazi Serdar Sariciftci, 2005.
4. New and future development in catalysis, Elsevier Publication, edited by Steven L. Suib, 2013.
5. Catalytic for renewables, Wiley-VCH Verlag GmbH & Co. KGaA, Edited by Gabriele Centi and Rutger A. van Santen 2007.
6. 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.

DGET615: INDUSTRIAL ENERGY AUDIT AND MANAGEMENT

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

- To provide an understanding on ECA-2001 and its features
- Need for energy audit and method of its execution
- The role of energy and material balance calculation in energy auditing
- To study the energy conservation opportunities in various thermal utilities
- Energy conservation in electrical utilities

Unit I: ECA-2001 & Energy Audit and Management [10]

Salient features of the ECA-2001, Key definitions, Powers and functions of BEE, State designated agencies, Schemes of BEE under ECA 2001, Need for energy audit, Types of energy audit, Identification of energy conservation (ENCON) opportunities, Technical and economic feasibility, Classification of ENCON measures, Energy audit report, Understanding of energy costs, Benchmarking, Plant energy performance, Fuel and energy substitution, Instruments and metering for energy audit.

Unit II: Material and Energy Balance [5]

Introduction, Components of material and energy balance, Basic principles of materials and energy balance, Classification of processes, Levels of material balance, Material balance procedure, Energy balance, Facility as an energy system, Energy analysis and Sankey Diagram.

Unit III: Energy Conservation in Thermal Utilities: Furnace, Boilers, Steam Systems [11]

Furnaces: Classification, general fuel economy measures in furnaces, excess air and heat distribution losses, temperature control, draft control, case studies.

Boilers: Types, analysis of losses, performance evaluation, boiler blow down, energy conservation opportunities, FBC boilers, case studies.

Steam system: Properties of steam, assessment of steam distribution losses, steam leakages, steam trapping, condensate and flash steam recovery systems, identifying opportunity for energy saving, case studies.

Unit IV: Energy Conservation in Thermal Utilities: Insulation and refractories [7]

Insulation and refractories: Insulation type and application, economic thickness of insulation, heat savings and application criteria, refractory-types, selection and application of refractories, case studies.

Waste heat recovery: Availability and reversibility, first and second law efficiency, classification, advantages and applications, commercially viable heat recovery devices, saving potential, case studies.

Unit V: Energy Conservation in Electrical Utilities [12]

Electrical systems and bill analysis: Electricity billing, electrical load management, maximum demand control, Energy conservation opportunities in Lighting systems, Electric motors, VCR and VCR systems, HVAC & refrigeration system, Fans & blowers, Pumps, case studies.

Text Books:

1. Albert Thumann, Terry Niehus, William J. Younger, HandBook of Energy Audits, River Publishers, 9th Edition.
2. Larry C. Witte, Philip S. Schmidt, David R. Brown, Industrial Energy Management and Utilization, 1st Edition, Springer Publication,1988.

References:

1. Carig B, Saith, Energy Management Principles, applications, benefit and saving, Per n Presss, Newyork
2. D Patrick and SW Fardo, Energy conservation, Prentice Hall, INC Engleweek Cliffs (NJ) 7632
3. Davida, Fuels of opportunity, characteristics and uses in combustion systems, Edition-2004, Publisher-Elsevier Ltd., UK
3. Stephen A. Roosa, Steve Doty, Wayne C. Turner, Energy Management Handbook, River Publishers, 9th Edition, 2018.
4. Giuliano Dall'O', Green Energy Audit of Buildings, Springer Publication, 2013.
5. Ian M. Shapiro, Energy Audits and Improvements for Commercial Buildings, Wiley Publication, 2016.
6. 6. F W Pyne, P gm Energy Conservation Manual, Fairmount Proem, INC. P.O. Box 14227 Atlanta, A30224

DGET616: ADVANCED BATTERY AND FUEL CELL TECHNOLOGIES

(Soft Core Course) **L T P C** **3 0 0 3 45L**

Course Outcome:

- Gain knowledge on components and working of lead-acid, lithium-ion batteries components
- Know-how on components and working of modern battery chemistries.
- Acquired know-how about fabrication and evaluation of lithium-ion battery
- Acquire knowledge on fabrication and evaluation of PEMFC fuel cell
- Get basic knowledge on electric vehicle and their markets in India and globally.

Unit I: SLI and VRLA Batteries [9]

Advantages and disadvantages of lead acid batteries, electrochemical reactions, physical and chemical properties of active materials, characteristics and properties of sulphuric acid, constructional features, materials and manufacturing methods, SLI (Automotive) batteries, charge and discharge properties of lead acid batteries, sealed lead acid or maintenance free batteries fabrication technology and testing. Lead acid battery for PV and automotive applications.

Unit II: Lithium-ion Battery [9]

Advanced anodes and cathodes – theoretical capacity – merits and demerits - Nanomaterials for anodes: carbon nanotubes, graphene, Sn, Al, Si, SnO_2, NiO and LTO. Nanomaterials for cathodes: $LiCoO_2$, $LiMn_2O_4$, $LiFePO_4$, and doped cathodes. Fabrication of nanostructured $LiCoO_2$, $LiMn_2O_4$, $LiFePO_4$, Si, Sn and CNTs. Battery fabrication technology and testing, batteries for electric vehicles, hybrid vehicles and solar photovoltaic applications.

Unit III: Post Lithium-ion Batteries [9]

Metal-ion Batteries: Na^+, K^+, Mg^{2+}, Al^{3+} & Ca^{2+}-ion batteries – Anodes, Cathodes, Electrolytes-Challenges & Advantages - Metal-Air Batteries: Lithium-Air, Sodium-Air, Zinc-Air batteries – Principle & components – anodes, cathodes, catalysts - fabrication - evaluation–merits and demerits and applications - Metal-Chalcogenides Batteries: Lithium-Sulphur, Sodium-Sulphur, Lithium-Selenium & Sodium-Selenium Batteries: Cathodes - Reaction Mechanism – Advantages - Challenges - Gravimetric & Volumetric energy density- Organic Batteries.

Unit IV: Fuel Cell Technology [9]

Membrane electrode assemblies, fabrication, catalyst layer, fuel cell supports, GDL, bipolar plates, fuel cell catalysts – precious and non-precious metal catalysts, bi-functional catalysts – nanomaterials for low temperature fuel cells – reversible fuel cells. Fuel cell stacks and systems - fuel cells for vehicles and grid connected applications.

Unit V: Electric Vehicle Technology [9]

Conventional vehicle Vs Electric vehicle: Concept of EV – Types of EV – Battery Technology– Motor types, Hybrid Electric Vehicle, Battery Pack and Battery Management system, Charging Technology, Future trends in EV: Wireless charging of EV - On-road charging of EV - Battery swap technology - Charging EVs from renewable - Government Policies, E-mobility: Indian and Word perspectives.

Text Books:

1. Modern Batteries Colin A Vincent and Bruno Scrosati, 1997 Pub Arnold ISBN 0-340-66278-6
2. Electric Vehicle Battery Systems Sandeep Dhameja, October 2001, Pub Newnes ISBN 0750699167

References:

1. T. R. Crompton, Battery Reference Book, SAE International, 1996.
2. Edition: 2EV/Hybrid Batteries & Battery Material Suppliers: An Automotive Market Review
3. David Linden, Hand Book of Batteries, McGraw-Hill, Inc, New York.
4. Linden D and Thomas B. Reddy, Hand book on batteries and fuel cell", McGraw Hill Book Co., New York, 3rd Edition, 2002.
5. Fuel Cell System Explained James Larminie and Andrew Dicks, 2003, Pub Wiley ISBN:0-470-84857-X
6. Energy conversion and storage scientific journals.

DGET617: ELECTRIC VEHICLE TECHNOLOGY

(Soft Core Course)

L T P C	
3 0 0 3	45L

Course outcomes:

- Get know about need of Electric Vehicles and their various types.
- Know-how technology of EV Architectures and their components
- Acquire knowledge on battery features for EV applications
- Get know-how technology of EV charging including wireless charging
- Awareness on Governments policies on EV and India & Global market trends.

Unit I: Introduction to Electric Vehicles [9]

Conventional Vehicles: Basics – Fuel types - transmission characteristics, Conventional vehicle vs Electric vehicle: Electric vehicle fundamental - History of electric vehicles, components: Battery system, motors, battery management system, thermal management system, Electronic controllers and convertors.

Unit II: Electric Vehicles & Architectures [9]

Types of electric vehicles: Battery electric vehicle (BEV) - Plug-in hybrid vehicles (PHEV)- Hybrid electric vehicles (HEV), Tractive effort in normal driving, Energy Consumption –the concept of Hybrid Electric Drive trains, Architecture of Hybrid electric drive trains.

Unit III: Energy storage for EV [9]

Energy Storage requirements, Battery parameters, Types of energy storage/devices (Lead-acid battery – lithium-ion battery & fuel cells): Nominal Voltage and Capacity, C rate, Energy and Power, Cells in series & Parallel, Charging and discharging process, Challenges and advantages, Hybridization of energy storage devices, modeling of batteries, Comparison of different energy storage technologies for EV, Fuel cell and Hybrid fuel-energy storage system.

Unit IV: Battery Management system [9]

Introduction to Battery Management System, Battery Pack topology, Voltage sensing, Temperature sensing, Thermal control, State-of-Charge and State-of-Health estimation, Cell balancing, cause of imbalance, circuits for balancing, Effect of distance, load and force on battery life and BMS, Energy Balancing with multi-battery system.

Unit V: Charging Technology and Future scope of EV [9]

Charging Technology, Future trends in EV, Overcharge and Undercharge, Modes of charging: Wireless charging of EV - On-road charging of EV - Battery swap technology - Charging EVs from renewable, Government Policies: FAME 1 – FAME 2, E-mobility: Indian and Global perspective.

Text Books:

1. Reachable lithium-ion batteries: Trends and Trends and Progress in Electric Vehicle Technology, P. Elumalai & T. Maiyalagan, CRC Press, ISBN 9781138484092.
2. Electric Vehicle Battery Systems Sandeep Dhameja, October 2001, Pub Newnes ISBN 0750699167.

Reference Books:

1. Larminie, James, and John Lowry, "Electric Vehicle Technology Explained" John Wiley and Sons, 2012. ISBN 978-1-119-94273-3
2. Plett, L. Gregory, "Battery Management Systems Volume 1", Artech House, 2015. ISBN 978-1-63081-023-8
3. Rui XIONG, Weixiang Shen "Advanced Battery Management Technologies for Electric Vehicles", John Wiley & Sons, 2019, ISBN 9781119481645.

DGET618: ADVANCED WIND ENERGY CONVERSION SYSTEM

(Soft Core Course) **LT P C 3 0 0 3 45L**

Course Outcome

After completion of the syllabus student able to:

- Understand the energy conversion techniques.
- Learn about wind turbine generator components and their constructions.
- Understand the modern wind turbine control & monitoring.

Unit I: Introduction to WECS [9]

Rotor Selection, Annual Energy Output, HAWT, VAWT, Rotor Design Considerations-Number of Blades, Blade Profile -2/3 Blades and Teetering, Coning- Upwind/Downwind, Power Regulation, Yaw System- Tower, Synchronous and Asynchronous Generators.

Unit II: Wind Energy Conversion System: Fixed Speed Systems. [9]

Generating Systems- Constant speed constant frequency systems -Choice of Generators- Deciding Factors-Synchronous Generator-Squirrel Cage Induction Generator- Model of Wind Speed- Model wind turbine rotor – Drive Train model-Generator model for Steady-state and transient stability analysis.

Unit III: Wind Energy Conversion System: Variable Speed Systems. [9]

Need of variable speed systems-Power-wind speed characteristics-Variable speed constant frequency systems synchronous generator- DFIG- PMSG -Variable speed generators modelling – Variable speed variable frequency schemes.

Unit IV: Modern Wind Turbine Control & Monitoring System [9]

Stall Control, Pitch Control, Details of Pitch System & Control Algorithms, Protections used & Safety Consideration in Wind turbines, Wind Turbine Monitoring with Error codes, SCADA & Databases:

Remote Monitoring and Generation Reports, Operation & Maintenance for Product Life Cycle, Balancing technique (Rotor & Blade), FACTS control & LVRT & New trends for new Grid Codes.

Unit V: Grid Integration [9]

Integration of Wind Energy Converters to Electrical Networks, Wind interconnection requirements, low-voltage ride-through (LVRT), ramp rate limitations, and supply of ancillary services for frequency and voltage control, current practices and industry trends wind interconnection impact on steady-state and dynamic performance of the power system including modelling issue.

Text Books:

1. C-Wet : Wind Energy Resources Survey in India VI
2. Duffie A. and Beckmann W. A., "Solar Engineering of Thermal Processes, John Wiley, 1991.

Reference Books:

1. Freris L.L., "Wind Energy Conversion Systems", Prentice Hall, 1990.
2. Godfrey Boyle, "Renewable Energy, Power for a Sustainable Future", Oxford University Press, 1996.
3. Kaldellis J.K., "Stand – alone and Hybrid Wind Energy Systems", CRC Press, 2010.
4. Mario Garcia –Sanz, Constantine H. Houpis, "Wind Energy Systems", CRC Press 2012.

DGET619: BIOREFINERIES

(Soft Core Course) **L T P C**
3 0 0 3 45L

Course Outcome:

Learn various methodologies to convert biomass to biocrude. Acquire knowledge on conversion of biomass feedstock to complex and value added biomolecules. Specifically gain understanding on developing end-to-end solution for biofuel production and commercially sustaining the process in algae based biofuel conversion process.

Unit I: Liquefaction of Biomass [6]

Biomass Feedstock -Thermochemical Conversion of Biomass – Liquefaction by Pyrolysis -Hydrothermal Liquefaction. Gasification -Biochemical Conversion- Pretreatment-Enzymatic Hydrolysis Fermentation.

Unit II: Biochemical Conversion & Metabolites [9]

Introduction -Primary Metabolites -Saccharides - Lignin
-Amino Acids, Peptides, and Proteins - Fatty Acids, Lipids -Organic Acids -SecondaryMetabolites
-Simple Phenols and Phenolic Acids -Polyphenols -Terpenes -Alkaloids - Stability of Isolated Compounds.

Unit III: Bio-separation Processes [12]

Conventional Separation Approaches-Steam Distillation-Conventional Solid–Liquid Extraction -Ultrasound-Assisted Extraction -Microwave-Assisted Extraction - Pressurized Subcritical Liquid Extraction -Supercritical Fluid Extraction -Separation and Purification of Phytochemicals from Plant Extracts and Dilute Solution in Bio-refineries -Liquid– Liquid Extraction -Membrane Separation-Molecular Distillation

Unit IV: Bio-refinery Concepts [9]

Classification of Biorefineries – Whole crop, Oleochemical, and Lignocellulosic Feedstock Biorefineries – Adoptability of Biorefineries in Petrochemical Refineries. Case studies: Specific Feedstock Based Biorefinery Process Development.

Unit V: Algal Bio-refinery [9]

Micro algae and Macro algae -Microalgae Biomass Production –Directed Algae Production Techniques -Down Stream Processing –Integrated Bioprocess in Algae - Value Added Chemicals from Biomass - Algal Phytochemicals, Biodiesel, Proteins, Polyunsaturated Fatty Acids, Vitamins, Carotenoids - Industrial products: Phycobiliproteins, Phycocolloids and Phycosupplements.

Text Books:

1. Biofuels Engineering Process Technology by Caye M. Drapcho, Nghiem PhuNhuan, & Terry H. Walker, McGraw Hill Publishers.
2. *Bioprocess Engineering Principles*; Pauline M Dorass, Academic Press.

Reference Books:

1. Ladisch, M.R., (2001), Bioseparation Engineering: Principles, Practice and Economics, Wiley, Interscience.
2. Biochemical Engineering Fundamentals; James E. Bailey and David F.Ollis, Mc Graw Hill book company.
3. Pauline M. Doran. Bioprocess engineering principles. Academic press. 1995
4. Biofuels from Plant Oils published by ASEAN Foundation (2010).
5. Industrial Biorefineries and White Biotechnology, Ashok Pandy et al (Editors), Elsevier 2015, ISBN :9780444634535

DGET620: ANAEROBIC DIGESTION AND BIOGAS TECHNOLOGY

(Soft Core Course) **L T P C**
3 0 0 3 45L

Course Outcome:

- After studying this subject, students would be able to understand the process of anaerobic digestion, microbial growth, and generation of biogas.
- Ability to analyze the optimum conditions for biogas production
- Design biogas and construct a proper size of the biogas plant.
- Perform testing of biogas plants and scale up the bioprocess
- Monitor the problems in biogas plants and repair the process for higher production efficiency

Unit I: Introduction to Biogas Systems [9]

Overview of gaseous biofuels; Traditional use of biogas in India; Potential of biogas in the energy scenario; Merits and demerits of biogas; Biogas in relation to ecology, environment, agriculture, health, and sanitation.

Unit II: Feedstock and Characterization **[**9]

Biogas feedstocks and characteristics; Agricultural waste; Industrial Wastes; Municipal wastes; Agro and processing industry wastes; processing and segregation of waste biomass; estimation of feedstock potential.

Unit III: Anaerobic Digestion [9]

Anaerobic digestion; principal of anaerobic digestion; biochemical and microbial aspects; Kinetics of biochemical conversions; rate-limiting reactions; single-phase vs. two-phase digestions; Composition and characteristics of biogas.

Unit IV: Biogas Systems and Storage [9]

Biogas plants/systems; classification and models of biogas plant; Types of bio-digesters; floating/fixed dome reactors; Design concept and construction of biogas plant; Up-gradation of biogas plant-CO_2 scrubbing-H_2S removal; operation and maintenance of biogas plant; Biogas storage, distribution, and utilization.

Unit V: Applications and Case Studies [9]

Biogas program in India; economic, social, and environmental aspects of biogas fuels; electricity from biogas; biogas based transport; Biogas appliances-CDM-Case studies

Text Books:

1. Hobson, P. N., & Wheatley, A. D. (1993). Anaerobic digestion: modern theory and practice.
2. Nijaguna, B. T. (2006). Biogas technology. New Age International.

Reference Books:

1. Horan, N., Yaser, A. Z., & Wid, N. (2018). Anaerobic Digestion Processes (pp. 978-981). Springer.
2. Lichtman, R. J. (1983). Biogas systems in India.
3. Chawla, O. P. (1986). Advances in biogas technology. Advances in biogas technology.9780444634535

DGET621: ALTERNATE MATERIALS FOR SUSTAINABLE TECHNOLOGY

(Soft Core Course) **L T P C**
3 0 0 3 45L

Course Outcome:

- A key feature of this subject will be to discuss an integrated approach combining advanced materials, fabrication, analytical, and modeling techniques for energy efficiency and environmental monitoring.
- It includes Sustainable construction materials, innovative building materials, Indoor air quality monitoring, and modeling and new sensing solutions for harvesting materials.

Unit I: Introduction to Sustainable Technology [9]

Introduction and definition of Sustainability. Sustainable construction, Carbon cycle and role of construction material such as concrete and steel, etc. CO2 contribution from cement and other construction materials. Prefabricated and pre-engineered buildings, High-performance concrete, Contemporary innovative building materials and their applications in Architecture, Alternate building materials and construction technologies.

Unit II: Construction materials and indoor air quality [8]

Construction materials and indoor air quality. No/Low cement concrete. Recycled and manufactured aggregate. Role of QC and durability. Life cycle and sustainability. Components of embodied energy, calculation of embodied energy for construction materials.

Unit III: Exergy concept and primary energy [8]

Embodied energy via-a-vis operational energy in conditioned building. Life Cycle energy use. Control of energy use in building, ECBC code, codes in neighboring tropical countries, OTTV concepts and calculations.

Unit IV: Structural Materials, Wall Systems and Flooring [10]

Natural /Conventional Building materials, Traditional and vernacular methods in India, Rammed earth construction, Hi-Tech Glass Polymers,Wall Systems: Framing, Insulation, Wallboards, Flooring, low VOC paints, materials & adhesives, building acoustics, Coating Materials, nanotechnologies for green buildings.

Unit V: Sustainable Material Measurement Properties [10]

Fibers- metal and synthetic, Fiber reinforced plastics, Matrix materials, Fibers organic and synthetic, Building materials from agro and industrial wastes, measurement of building materials properties calculations and carbon footprint calculation.

Text Books:

1. Wu Chung, H. Advanced Civil Infrastructure Materials, First Edition, Woodhead Publishing Limited, 2006
2. Newman, J. and Choo, Ban Sang, Advanced Concrete Technology-Processes, 1st Edition, Elsevier, 2003.

Reference Books:

1. Newman, J. and Choo, Ban Sang, Advanced Concrete Technology-Constituent Materials, 1st Edition, Elsevier, 2003.
2. Sustainability of Construction Materials, A volume in Woodhead Publishing Series in Civil and Structural Engineering Edited by J. Khatib ISBN: 978-1-84569-349-7
3. Kubba, S, LEED Practices, Certification, and Accreditation Hand book, 1st ed. Elsevier, 2010.
4. Venkatarama Reddy, B. V., and. Jagadish, K., S. “Embodied energy of common and alternative building materials and technologies”. Energy and Buildings., 35, 129- 137,2003.
5. Chani, P. S., Najamuddin., and Kaushik, S.K. “Comparative Analysis of Embodied Energy Rates for Walling Elements in India”. Energy and Buildings., 84, 47-50. 2003.
6. Andrew, H., Buchanan., and Brian, G. “Energy and carbon dioxide implications of building construction”, Energy and Buildings., 20, 205-217. 1994.

DGET622: BIOMASS FEEDSTOCK AND SOLID BIOFUEL PRODUCTION

L T P C

(Soft Core Course) **3 0 0 3 45L**

Course Outcome:

- Students shall able to assess regional biomass potential for energy conversion.
- Learn the process and technology to develop solid biofuels from available biomass
- Learn various solid biofuels processing technology and their commercial potential.

Unit I: Biomass Resources [9]

Agricultural produce and waste biomass, Biomass from forest produce and energy plantation, Aquatic weeds, Marine resources. Biomass yield, availability, energy potential. Industrial biomass, Biomass from urban and municipal wastes, Seasonal biomass feedstock.

Unit II: Resource Assessment of Biomass [9]

Interaction of biomass with electromagnetic spectrum –Principle of remote sensing and its application to biomass quantification – 3D remote sensing, Vegetation indices - Analysis of satellite imageries for biomass quantification, SAR, UAV based biomass estimation. Biomass feedstock potential in India - Regional biomass availability - Case studies.

Unit III: Processing of Biomass [9]

Physical properties of biomass: Moisture, bulk density, size, grindability, crushability. Chemical composition of biomass- estimation of volatile matter, cellulose, hemicellulose and lignin content. Properties of municipal solid waste – Segregation of paper and plastic waste – refuse derived fuels.

Unit IV: Solid Biofuel Production Processes [9]

Pelleting and briquetting of solid biomass – Process flow – factors influencing heat values. Pretreatment of biomass for energy enhancement – Torre faction, Fuel characteristics of solid biofuels - co-firing of solid biofuels in thermal power plants – application in industrial units, Industrial production of pellets and briquettes – Integrated process flow - feedstock andproduct portfolios – Securing feedstock supply chain.

Unit V: Energy Economy of solid biofuel [9]

Roll of biomass energy in energy security - energy economy of solid biofuel - regional biomass utilization- Entrepreneurships potential- International and national energy policies on solid biofuels – Integrated economy model in solid biofuel Production – Case studies.

Text books

1. Industrial briquetting: fundamentals and methods, Vol.13. Studies in Mechanical Engineering by Zygmunt Drzymała, Elsevier, 1993.
2. Biomass Briquetting: Technology and Practices by P.D.Grover & S.K.Mishra, published by FAO Regional WoodEnergy Development Programme in Asia, Bangkok, Thailand

Reference books:

1. Chakraverthy A, "*Biotechnology and Alternative Technologies for Utilization of Biomass Or AgriculturalWastes"*, Oxford & IBH publishing Co, 1989.
2. VenkataRamana P and Srinivas S.N, "*Biomass Energy Systems*", Tata Energy Research Institute, 1996.
3. Application and Problems of Biomass Briquetting Densification Fuel(BBDF) Technology in Chi na by Wang Xutao and Zhang Bailiang, Springer Berlin Heidelberg.
4. David Boyles, Bio Energy Technology Thermodynamics and Costs, Ellis Hoknood Chichester, 1984.
5. Mahaeswari, R.C. Bio Energy for Rural Energisation, Concepts Publication,1997
6. Best Practises Manual for Biomass Briquetting, I R E D A, 1997

DGET623: ORGANIC PHOTOVOLTAICS

(Soft Core Course) **L T P C**
3 0 0 3 45L

Course Outcome:

- To evaluate how these materials can be implemented successfully in established and emerging organic electronic modules.
- Able to link molecular transport phenomena with macroscopic device response to analyze and design the next generation of organic electronic materials and devices.
- Demonstrate ability to plan synthetic strategies at an advanced level in order to synthesize organic optoelectronic materials.
- Able to propose different synthetic routes in order to enrich the properties of the material through rational understanding of structure-property relationships.

Unit I: Introduction to organic materials [9]

Introduction to organic materials for energy as a class of materials of great potential. Different classes of organic electronic materials, namely small molecule semiconductors, conjugated polymers, and carbon nanostructured materials and the main concepts. Organic optoelectronic devices, structure, principles and performances.

Unit II: Molecular, Thermal, Structural and Optical Characterization [9]

Molecular, Thermal, Structural and Optical Characterization methods to analyze different material properties. Electronic Structure, Atomic and Molecular Orbitals, The Fermi Energy and The Density of States. Carrier Densities in Intrinsic Semiconductors. Charge Transport. Doping in Semiconducting Materials. Transport in Disordered Semiconductors.

Unit III: Organic Photovoltaic Devices [9]

Organic Polymer-based Solar cells, Plastic cells, perovskite solar cells, Field-Effect Transistors and Light Emitting Devices. Overview of Organic Photovoltaic Devices. Characterizing Device Parameters in OPVs. Nanostructural Impacts in OPV Devices. Interfacial Modifying Layers in OPV Devices. Emerging Trends in OPV Devices

Unit IV: Optoelectronics [9]

Photovoltaic and Emerging Devices. Introduction to Organic Light-emitting Devices. Design Considerations for OLEDs. Introduction to Polymer Thermoelectric Devices. State-of-the-Art in Polymer Thermoelectrics. Determination of figure of merit and device characteriazation.

Unit V: Development of organic Materials [9]

Structure-property relationship in organic electronic materials. Tuning of the chemico-physical properties by synthesis and functionalization of the molecular structure. Key aspects in the development of organic-based devices; material design, structure and properties, interfaces, solid state aggregation and morphology of the active layer, charge transport, device architecture and long-term stability.

Text books:

1. Organic Optoelectronics - Wenping Hu, Fenglian Bai, Xiong Gong, Xiaowei Zhan, Hongbing Fu, Thomas Bjornholm, Wiley, ISBN: 978-3-527-65345-4; 2013.
2. Solar Photovoltaics: Fundamentals, Technologies and Applications, C. S. Solanki, Prentice Hall of India, 2011.

Reference books:

1. Organic photovoltaics: Concepts and realization - C. Barbec, V. Dyakonov, J. Parisi, N. S. Saricifttci, Springer-Verlag 2003.
2. Advances in Carbon Nanomaterials: Science and Applications (1st ed.) - Tagmatarchis, N. (Ed.). (2012). Jenny Stanford Publishing.

DGET610: ENERGY LABORATORY – III
(VIRTUAL INSTRUMENTATION AND CASE STUDIES ON SUSTAINABLE ENERGY SYSTEMS)

LTPC

(Hard Core Course) **0 2 4 3 90L**

Course Outcome:

- Gain simulation and modeling skill.
- Apply computational and programming skill set to solve renewable energy technology related problem.
- Acquire basic concept of virtual instrument based programming and interfacing.
- Learn the programing skill to control and interact with devices in real-time.

List of Experiments

S. No.	List of Experiments
1	Simulation of wind turbine
2	Simulation of wind generator
3	Simulation of hybrid wind-solar system
4	Experimental study on effects of blade profiles on the Performance of the wind turbine
5	Experimental study on effects of loads on the energy output of a wind turbine
6	Experimental study on flow behavior over the wind turbine
7	Experimental study on solar – wind hybrid energy system performance
8	Computational study on effects of blade profiles on the Performance of the wind turbine
9	Computational study on effects of loads on the energy output of a wind turbine
10	Computational study on flow behavior over the wind turbine
11	Computational study on solar – wind hybrid energy system performance
12	The casting of eco-friendly concrete blocks for Green Buildings
13	Carbon Emission Test of construction Materials for Green Buildings
14	Thermal Properties of Green Building Materials
15	Evaluation of Mechanical Properties of residues for Green Building applications

Virtual Instrumentation and Case Studies

The trend engineering design today, is towards more digital prototyping and computer-based evaluation and testing before a time-consuming and expensive production of either scale models or full-size physical prototypes of components or systems. During this lab course, the student is expected to gain practical experience on case studies related to alternate and green technologies. Students will be given the opportunity to develop a detailed prototype interactive virtual instrumentation system for a sustainable energy project that they can use as the basis of their final industrial project, to be pursued at the fourth semester. Students are expected to give two seminars and submit a system document that must include sufficient technical content along with resource assessment, economic appraisal, development schedule and plan as well as environmental, economic and social impact assessment.

Course Contents

Virtual Instrumentation basics: Front panel and block diagram- Dataflow programming model Modular Programming: Basics of modular programming with subVIs- Creating an icon and connector pane Graphing with LabVIEW: Using waveform charts to display data, XY graphs to display data

Strings and File I/O: Creating string controls and indicators, Using File I/O Vis.

Data Acquisition: Plug-in DAQ devices, Performing analog I/O, Counters, Digital I/O, Instrument Control, Sensors and Transducers, PC Based Measurement Data Acquisition & Signal Conditioning., Intelligent Instrumentation.

Manuals & References:

1. LabVIEW for Data Acquisition (Paperback) Bruce Mihura Prentice Hall, 2001
2. LabVIEW for Electric Circuits, Machines, Drives, and Laboratories, by Nesimi Ertugrul, Prentice Hall 2002
3. LabView: Advanced Programming Techniques, SECOND EDITION Rick Bitter,
4. Taqi Mohiuddin, Matt Nawrocki CRC Press; 2 edition, 2006
5. LabVIEW for Everyone: Graphical Programming Made Easy and Fun (3rd Edition) (Hardcover)~ Jeffrey Travis,
6. Jim Kring Prentice Hall; 3 edition 6, 2006

The virtual instrumentation case studies investigated in this lab are expected to include Renewable /Non-Conventional Energy Systems- Solar, Wind, Small Hydro, Biofuels, Solar thermal & Solar PV systems. Types of Solar energy convertors, Wind Energy Conversion Systems, Wind data analysis, Grid connected systems, Mini/Micro/Pico hydel Systems-Turbines, Grid connected and stand-alone systems, Bio fuels- Biogas. Bio mass. Bio diesel, Gasifiers, Hybrid systems, Energy conservation and Energy Efficiency, Intelligent buildings.

Manuals & References:

1. Study of Electrical Power Systems Using LabVIEW Virtual Instruments (VI) Modules Paper 137, Proceedings of the 2008 IAJC-IJME International Conference ISBN 978-1-60643-379-9
2. A LabView Based Instrumentation System for a Wind-Solar Hybrid Power Station Journal of Industrial Technology • Volume 20, 2004, 1-8
3. Design and Simulation of an Automated System for Greenhouse using LabVIEW, American- Eurasian Journal and Environmental Science, 2008, vol 3, 279-284.
4. Using LabVIEW in a Mini Power System Model Allowing Remote Access and New ImplementationsInternational Conference on Engineering Education – ICEE 2007, September 3 – 7, 2007
5. A Matlab-Based Modeling and Simulation Package for Electric and Hybrid Electric Vehicle Design IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 48, NO. 6, NOVEMBER 1999

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SEMESTER - IV

DGET640: GREEN TECHNOLOGY DISSERTATIONS

(Hard Core Course) Full-time Dissertation work

Course Outcome:

- Student shall specialize through industrial training and/or research work in the renewable energy field of their choice & basic degree specialization
- Learn to identify a research problem or industrial problem, devise a methodology to solve the same.
- Trained on design, fabrication and testing of energy products
- Learn the entrepreneurship potential in renewable energy technologies.

Course Code	Course Title	Course Type*	L	T	P	C
DGET640	Green Energy Technology Dissertation & Viva-voce	H				12
Total No. of Credits						**12**

To be carried out with due permission from the Chairperson / Coordinator for one semester (four months) in any industry or a research organization outside Pondicherry University and practicing green energy technologies

A thesis written for this project will be evaluated by an expert followed by viva-voce.

Minimum credit requirement = 72; All teaching, learning and evaluations will follow the Choice Based Credit System (CBCS) which is in vogue in Pondicherry University.

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OTHER SOFT-CORE COURSES

These courses will be offered in any of the first three semesters depending on the availability of the resource faculty.

DGET624: GREEN MANAGEMENT

(Soft Core Course) **L T PC**
3 0 0 3 **45L**

Unit I: [9]
The concept of green management; evolution; nature, scope, importance and types; developing a theory; green management in India; relevance in twenty first century

Unit II: [9]
Organizational environment; internal and external environment; Indian corporate structure and environment; how to go green; spreading the concept in organization; Environmental and sustainability issues for the production of high-tech components and materials, life cycle analysis of materials, sustainable production and its role in corporate social responsibility (CSR) and corporate environmental responsibility (CER).

Unit III: [9]
Approaches from ecological economics; indicators of sustainability; ecosystem services and their sustainable use; bio-diversity; Indian perspective; alternate theories

Unit IV: [9]
Environmental reporting and ISO 14001; climate change business and ISO 14064; green financing; financial initiative by UNEP; green energy management; green product management

Unit V: [9]
Definition; green techniques and methods; green tax incentives and rebates (to green projects and companies); green project management in action; business redesign; eco-commerce models

Textbooks:

1. Green Management and Green Technologies: Exploring the Causal Relationship by Jazmin Seijas Nogarida, 2008.
2. Green Marketing and Management: A global Perspective by John F. Whaik, 2005

References:

1. The Green Energy Management Book by Leo A. Meyer
2. Green Project Management by Richard Maltzman And David Shiden
3. Green Marketing by Jacquelin Ottman
4. Green and World by Andrew S. Winston

DGET625: BIO -INDUSTRIAL SKILLS

(Soft Core Course) **LT PC**
3 0 0 3 45L

Course outcome:

- Become aware of the practical issues when they enter the industry for employment
- Getting a sense of what industries expect for successful employment
- Understanding the problems analytical planning of hands on experience
- Acquisition of skills needed for decision making

Unit I: Demand of the Industry [9]

Contemporary industry's need of products, economical value, hard and soft expertise, does and don'ts, standard operating procedure (SOP), organization management, genuineness, hands on experience.

Unit II: Planning research proposal [9]

A well-defined sketch goal, state of art the technology, essential reachable objectives, designing vital methodology, procedural work plan, time line millstone, hindrance management, deliverable outcome, budget, revenue generation,

Unit III: Plan of action [9]

Task management, procedural knowledge, documentation (log note/observation note), result interpretation, managing problem, technology development, intellectual property rights (IPR), commercial production/scale up of production, and managing problem at scale up production.

Unit IV: Decision making [9]

Identification of the problem, analysis of problem, gather relevant information, development of alternatives, evaluation of alternatives, selection of best alternatives, implementation of alternatives, review of implementation.

Unit V: Mandatory skills [9]

Basic information about the mandatory skills required by the industry/organization includes technical skills, management skills, analytical skills, leadership skills, collaborative skills, learning skills, presentation skills, innovation/creative skills, dedication skills.

Text Books

1. Dinkar Pagare, Business Management, 2018
2. Ben-Daya, Mohamed; Duffuaa, Salih O; Raouf, Abdul; Knezevic, Jezdimir; Ait-Kadi, Daoud (2009). *Handbook of Maintenance Management and Engineering, 10.1007/978-1-84882-472-0(),* –. doi:10.1007/978-1-84882-472-0

Reference books

1. C. George Thomas, (2021) Research Methodology and Scientific Writing, Springer, Cham, 2nd ed, ISBN: 978-3-030-64865-7, https://doi.org/10.1007/978-3-030-64865-7.
2. Peters, G., & Svanström, M. (2019). Decision-Making. In *Environmental Sustainability for Engineers and Applied Scientists* (pp. 198-226). Cambridge: Cambridge University Press. doi:10.1017/9781316711408.010
3. B.Narayan (1999) Industrial Management, APH Publishing, ISBN 817648038X, 9788176480383, 280 pages.

DGET626: BIOPROSPECTING TECHNOLOGY FOR BIOFUEL PRODUCTION

(Soft-core Course) **L T P C**
3 0 0 3 45L

Course outcome:

- Gain the knowledge on bioprospecting of microbial stains for biofuels production
- Obtain insight about the merits and demerits of energy plants
- Familiarize the instruments used in biofuels estimation
- Understanding the goals of Zero waste management

Unit I: Bioprospecting of Microbial strains [9]

Biofuel strains, potential to utilize high substrates, high tolerance to inhibitors and end products, great metabolic efficiency, bioprospecting for wild strains with the target gene, fermentation with metabolically engineered strains.

Unit II: Bioprospecting of Energy plants [9]

Food versus Fuel, Reliability of Feedstock Supply, Shared Economic Prosperity, Environment-Water Availability, Nutrient Run Off, Land-use Change, Residue Diversion, Introduction of Invasive Species, Validity of GHG, Competitiveness

Unit III: Bioprospecting of Environmental samples [9]

Bioprospecting for Cellulose, hemicelluloses, lignin-Degrading Microbes- Filter Paper Assay method, xylanase assay, zymogram, High concentrations of cellulosic biomass, Evidence of decomposing cellulosic biomass, Moist conditions, warm conditions.

Unit IV: Instrumentation in biofuel [9]

High performance liquid chromatography- UV detector, PDF detector, HPLC columns for specific sample, solvent system, degasification, Gas chromatorgraphy, FID, TCD, carrier gases, ignition gas, GC columns.

Unit V: Zero waste management [9]

Bioprospecting of lignocellulose and starch waste to ethanol, butanol, bioprospecting organic waste into hydrogen, bioprospecting of microbial biomass as animal feed, bioprospecting of marine- fresh algal biomass for biofuel production

Text Books:

1. Bioprospecting, Russell Paterson, Nelson Lima (eds), Springer, Cham, 2017, https://doi.org/10.1007/978-3-319-47935-4.
2. Zero Waste Biorefinery, Yogalakshmi Kadapakkam Nandabalan, Vinod Kumar Garg, Nitin K. Labhsetwar, Anita Singh (eds), Springer, Singapore, 2022, ISBN: 978-981-16-8682-5, https://doi.org/10.1007/978-981-16-8682-5

Reference books:

1. Genetic and Metabolic Engineering for Improved Biofuel Production from Lignocellulosic Biomass, Arindam Kuila, Vinay Sharma (eds), Elsevier, 2020, 978-0-12-817953-6, https://doi.org/10.1016/C2018-0-02516-5.
2. Neha Srivastava, P.K. Mishra and S.N. Upadhyay, Industrial Enzymes for Biofuels Production: Recent Updates and Future Trends, Elsevier, 2020, 978-0-12-821010-9
3. Nikalje, Anna. (2017). A Handbook of Chromatography.

DGET627: MICRO HYDROPOWER ENERGY SYSTEM

(Soft-core Course) **L T P C**
Course outcome: **3 0 0 3 45L**

- To learn an idea of designing and selecting of civil components, mechanical components, electrical components, and transmission system.
- Students learn the basic components of a Micro Hydropower System to design an MHP System and able to select the suitable system components. Also, able to know how to transmit the power and to distribute in an efficient way.

Unit I: Introduction to Micro-Hydropower Technology (MHP) [8]
Introduction to MHP system design, Planning concepts, Evaluation of MHP requirements, Power from water, Classification of hydropower and end-users, System components of Mini and Micro Hydropower, Introduction of Hydropower plant in India, Micro Hydropower plant in India, Policy of India Government and concerned authorities, Potential Hydropower plant projects identified in India, Water management

Unit II: Layout design of civil components of MHP system [9]
Overview of civil components of MHP system, Intake, and weir. Headrace canal, Spillway, Settling basins, Fore-bay, Penstock, Anchor blocks, Support piers, Expansion joints, Powerhouse.

Unit III: Design and Selection of mechanical components of MHP system [10]
Selection of turbines and its components, Selection of the turbine based on load demand, Valves, Plant efficiency, Power output calculation, Turbine sizing
Selection of electro-mechanical equipment: Introduction of different belts: Vee belt, tooth belt, flat belt , Selection of belt, Pulley: Introduction of pulleys, Coupling :Introduction of different couplings, Selection of couplings, Gear box, Safety measures of MHP equipment, De-silting basin, Fore-bay structure, Water convey pipe line, Valves, Turbines, Belt and coupling

Unit IV: Selection of electrical components of MHP scheme [10]
Generator - type and size (a) Synchronous generator, (b) Induction generator; Selection of generator type; Determination of size of generator; Speed governing system-Conventional oil pressure mechanical governor, Electronic governor
Selection of Transformer: Introduction of transformer, Constructional details of transformer, Selection of transformer rating and specification, Operation and maintenance of transformer, Safety measures.

Unit V: Selection of Transmission and Distribution Lines [8]
Selection of transmission voltage, Selection of underground or overhead lines, Sizing of overhead transmission line conductor, Installation of transmission and distribution lines, Grid connection of MHP plant.

Text books:

1. Adam Harvey, "Micro Hydro design Manual", Intermediate Technology Publication.
2. Win Hulsher and Peter Frankel, "The Power Guide, Intermediate Technology Publication.

Reference books

1. "Manuals on MHP for Installation and Commissioning, Maintenance and Repair, Operation and Management", ICIMOD.
2. Small hydroelectric engineering practice- Bryan Leyland, CRC Press
3. Hydropower Engineering- C.C. Warnik, Prentice Hall.

DGET628: SUSTAINABLE TECHNOLOGIES FOR VALORISATION OF WASTE CARBON FEEDSTOCKS

(Soft Core Course) **L T P C**
3 0 0 3 45L

Course Outcome:

- Able to understand and integrate circular economy for sustainable development.
- To understand the applications of newer technologies for the better process integration in waste-based refineries.
- To realize techno-economic considerations and challenges, for conversion of waste to value, and role of government policies.

Unit I: Circular Economy for Waste Reduction and Carbon Footprint [9]

Introduction: Carbon's critical role as life essential element and in non-renewable fuels and chemicals. Various sources of carbon waste eg., industrial emissions, biomass residue, manure, garbage which are of environmental concern. Circular economy as a new rational utopia. Integration of Circular economy and Sustainable Development. Requirements for Transition to a Circular Economy. Possible supply chain scenarios for conversion of waste carbon to valuable products.

Unit II: Carbon abatement technologies [9]

Emerging carbon abatement technologies to mitigate carbon footprint and convert to carbon-based chemicals and valuable products.

General approach for waste treatment and conversion to value-added products: biochemical, mechanical, and thermochemical. Valorisation of woody biomass, challenges therein. Process integration for waste-based biorefinery. Recovery of valuable products from anaerobic digestion of food waste. novel biotechnological processes and chemical transformations. Comparing various waste to energy (WtE) Technologies.

Unit III: Technologies for CO_2 conversion to valuable chemicals [9]

Overview of potential chemical pathways to use CO2 for the production of polymers. CO2 conversion technologies: Urea production, Sabatier synthesis, Fischer-Tropsch synthesis, hydrogenation to methanol, dry reforming, hydrogenation to formic acid, and electrochemical reduction. Potential of advanced catalytic materials such as metal organic frameworks, (MOFs), covalent organic frameworks (COFs), and technologies in photocatalytic, electrochemical, photoelectrochemical, biocatalytic and thermal reduction of CO2 to valuable chemicals.

Unit IV: Technologies for biomass volarization to value-added products [9]

Important reactions in biomass conversion include hydrolysis, isomerization, dehydration, hydrogenation, hydrodeoxygenation, hydrogenolysis, oxidation, esterification, ketonization, condensation, Aldol reaction and others. Concepts in advanced catalytic materials and techniques such as thermochemical catalysis, photocatalysis, electrocatalysis, photoelectrocatalysis, and biochemical technologies biomass volarization and challenges. Catalytic machanisms in valorization of Lignin, and cellulose-based biomass to platform chemicals.

Unit V: Techno-economic challenges, government policies and case studies [9]

Techno-economic considerations and challenges which impede the conversion of waste into a more valuable product: advances in industrial biotechnology, production organic chemicals using renewable feedstocks such as agriculture and forestry residues and energy crops, including switchgrass among others, and the challenges/ drawbacks therein.

Factors that determine investments to use waste carbon as chemical feedstocks. Government Policies. Case studies. Potential business model.

Text books:

1. Green Carbon Dioxide: Advances in CO2 Utilization - Gabriele Centi, Siglinda Perathoner ISBN: 978-1-118-59088-1 March 2014.
2. Waste Valorisation: Waste Streams in a circular economy - Carol Sze Ki Lin, Guneet Kaur, Chong Li, Xiaofeng Yang, Christian V. Stevens, Wiley, ISBN: 978-1-119-50270-8; 2020.

References:

1. Sustainable Bioconversion of Waste to Value Added Products - Inamuddin, Anish Khan, Springer Cha, ISBN978-3-030-61839-1; 2021.

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