PONDICHERRY UNIVERSITY

PONDICHERRY – 605 014

MADANJEET SCHOOL OF GREEN ENERGY ECHNOLOGIES

DEPARTMENT OF GREEN ENERGY TECHNOLOGY

uilding for MSGET

Ph.D. Program in Green Energy Technology

(To be effective from 2022-23)

DEPARTMENT OF GREEN ENERGY TECHNOLOGY

MADANJEET SCHOOL OF GREEN ENERGY TECHNOLOGIES
PONDICHERRY UNIVERSITY, PONDICHERRY – 605 014, INDIA

Ph.D. (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.

Ph.D. offered at Pondicherry University in Green Energy Technology is cutting-edge research on Green Energy Technology and its related areas. 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

List of Papers for PhD Course Works

Course Code	Title of the course	Marks			Credits
		Internal	External	Total	
DGET901	Research Methodology (Scientific Writing, Energy and Environment)	40	60	100	3
DGET902	Research and Publication Ethics	40	60	100	2

Course Code	Title of the course	Marks			Credits
		Internal	External	Total	
DGET911	Bioenergy and Bio photonics	40	60	100	3
DGET912	Bioenergy and Conversion Systems	40	60	100	3
DGET913	Solar Thermal Energy: Fundamentals, Devices And Systems	40	60	100	3
DGET914	Nanomaterials: Properties, Synthesis, Characterization and Applications	40	60	100	3
DGET915	Electrochemical Energy Conversion and Storage	40	60	100	3
DGET916	Modelling and Simulations of Green Energy systems	40	60	100	3
DGET917	Nanotechnology for Energy Systems	40	60	100	3
DGET918	Solar Photovoltaic Energy Conversion	40	60	100	3
DGET919	Algal Energy Technology	40	60	100	3
DGET920	Wind Energy Technology	40	60	100	3
DGET921	Solar Photovoltaic Power Systems	40	60	100	3
DGET922	Microbial Technology for Biofuel Production	40	60	100	3
DGET923	Computational Fluid Dynamics for Energy Engineering	40	60	100	3
DGET924	Green Building and Sustainable Development	40	60	100	3
DGET925	Artificial Intelligence, Machine Learning and Data Analysis for Photovoltaic Systems	40	60	100	3
DGET926	Anaerobic Digestion and Biogas Technology	40	60	100	3
DGET927	Bioprospecting Technology for Biofuel Production	40	60	100	3
DGET928	Micro Hydropower Energy System	40	60	100	3
DGET929	Alternate Materials for Sustainable Technology	40	60	100	3

DGET930	Carbon sequestration at the Landscape level	40	60	100	3
DGET931	Bioprocess Engineering for Biofuels	40	60	100	3
DGET932	Advanced Polymeric Materials for Renewable Energy Systems	40	60	100	3
DGET933	Industrial Energy Audit and Management	40	60	100	3
DGET934	Advanced Battery and Fuel Cell Technologies	40	60	100	3
DGET935	Electric Vehicle Technology	40	60	100	3
DGET936	Advanced Wind Energy Conversion System	40	60	100	3
DGET937	Biorefineries	40	60	100	3
DGET938	Biomass Feedstock and Solid Biofuel Production	40	60	100	3
DGET939	Bio Industrial Skills	40	60	100	3
DGET940	Green Chemical Technologies	40	60	100	3
DEGT941	Organic Photovoltaics	40	60	100	3
DGET942	Sustainable Technologies for Valorization Of Waste Carbon Feedstocks	40	60	100	3
DGET950	Research Seminar (Two Research Seminar has to be presented)				

Instructions:

- Candidates with M.Tech/M.Phil. are exempted from the course works. However, the candidate has to take the Research Ethics paper. The Doctoral Committee may recommend additional papers if required.
- Doctoral committee will recommend any two papers from the above list or the Doctoral Committee may recommend one or two papers from other departments/Centers offered at M.E./M.Tech/Ph.D. level.
- The examination will be conducted by the Research Supervisor with the information to the Head of the Department.
- Research Seminar is compulsory for all Ph.D. scholars.

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Research Area and Eligibility Requirement of the Ph.D. (GET) Programme from the academic year 2022-23:

Research area	Eligibility for Admission to Ph.D. Programme
Bioenergy/Biofuels /Combustion Technology	**M.Sc.** Biotechnology/Bioenergy/Microbiology/Environmental Science /Marine Science **OR** **M.E/M.Tech.** Energy/ Green Energy Technology/ Nanotechnology / Biotechnology/Environmental Engineering
Energy Materials/Energy Conversion & Storage	**M.Sc.** Physics/ Chemistry (with allied Mathematics at BSc level)/ Materials Science **OR** **M.E/M.Tech.** Materials/Energy/Green Energy Technology with B.E./B.Tech in Chemical Engineering/Electronics/Electrical Engineering
Solar Thermal Energy Technology	**M.Sc.** Physics/ Material Science **OR** **M.E/M.Tech.** Energy/ Thermal Engineering/Green Energy Technology
Photovoltaic Technology	**M.Sc. -**Physics/ Material Science **OR** **M.E/M.Tech.**Material Science/ Nanotechnology /Energy/ Green Energy Technology with B.E /B.Tech in Material Science /Electronics/Electrical Engineering
Organic Photovoltaics and Green Chemical Technologies	**M.Sc.** Chemistry /Materials Science/ Nanoscience **OR** **M.E/M.Tech.** Energy/Green Energy Technology/ Nanotechnology/Material Science/Energy Science and Technology
Wind/Ocean/Tidal Energy Technology	**M.Sc.** Physics/Chemistry (with allied Mathematics at BSc. level) /Materials Science/Nanoscience **OR** **M.E/M.Tech.** Energy/Mechanical/Material/Civil/Green Energy Technology with B.E./B.Tech in Mechanical/Electronics/Electrical Engineering **OR** **M.Tech** Energy/ Thermal Engineering/Green Energy Technology
Green Building/Sustainable Technology	

DGET901: RESEARCH METHODOLOGY
(SCIENTIFIC WRITING, ENERGY AND ENVIRONMENT)

Contact Hours: 45 Hours

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 analyses 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: Scientific writing and research methodology [9]

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

Unit II: Data acquisition and analysis [9]

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

Unit III: Green Energy technology: Research Challenges [9]

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

Unit IV: [9]

To be given by Doctoral Committee

Unit V: [9]

To be given by Doctoral Committee.

Text books:

1. E H Thorndike, Energy & Environment: A Primer for Scientists and Engineers, Addison- Wesley Publishing Company
2. R Wilson & W J Jones, Energy, Ecology and the Environment, Academic Press Inc.

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

DGET902: RESEARCH AND PUBLICATION ETHICS

Contact Hours: 30

Course Outcome:

- To understand the philosophy of science and ethics, research integrity, and publication ethics
- To identify research misconduct and predatory publications.
- To understand indexing and citation databases, open access publications, and research metrics (citations, h-index, impact Factor, etc.).
- To understand the usage of plagiarism tools.

Student Outcomes:

At the end of the course, the student will have awareness of the publication ethics and publication misconduct.

Unit I: Philosophy, Ethics and Scientific Conduct [6]

Introduction to philosophy: Definition, nature and scope, concept, branches – Ethics: definition, moral philosophy, nature of moral judgements and reactions - Interpersonal relations and code of conduct at work place - Institutional regulations: Behavioral rule, customs and norms. Ethics with respect to science and research - Intellectual honesty and research integrity - Scientific misconducts: Falsification, Fabrication and Plagiarism (FFP) – Redundant Publications – Duplicate and overlapping publications, salami slicing - Selective reporting and misrepresentation of data.

Unit III: Publication Ethics **[**9]

Definition, importance of ethical practice in research publication - Best practices / standards setting initiatives and guidelines: COPE, WAME, etc. - Conflicts of interest definition and avoidance - Publication misconduct: definition, national and international implications – institutional norms - Violation of publication ethics, authorship and credit to contributors - Identification of publication misconduct, complaints and appeals - Predatory publishers and Journals. Ethics of collaborative

research – convention, MoA, MoU and norms. Contract Research and confidentiality agreements/non-disclosure agreements. Ethics of deriving and preserving IPR – Patenting ethics.

Unit IV: Publishing and Publication Misconduct **[**9]

Types of research publications – Subscription Vs Open access publications - Open access publication initiatives - SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies - Software tool to identify predatory publications developed by SPPU - Journal finger / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer, Journal Suggester, etc. Subject specific ethical issues, FFP, authorship, Conflicts of interest, Complaints and appeals: Case studies on unethical practices reported in India and Abroad - Software tools.

Unit V: Publications Tools and Metrics **[**6]

Use of plagiarism software like Turnitin, Urkund and other open-source software tools. Databases: Indexing databases, Citation databases: Web of Science, Scopus, etc. Research Metrics: Impact Factor of journal as per Journal Citations Report, SNIP, SJR, IPP, Cite Score - Metrics: h-index, g index, i10 Index, altmetrics. Other emerging tools and concepts.

Text books:

1. Nicholas H. Steneck. Introduction to the Responsible Conduct of Research. Office of Research Integrity. 2007. Available at: https://ori.hhs.gov/sites/default/files/rcrintro.pdf
2. The Student's Guide to Research Ethics By Paul Oliver Open University Press, 2003

References:

1. Responsible Conduct of Research By Adil E. Shamoo; David B. Resnik Oxford University Press, 2003
2. Ethics in Science Education, Research and Governance Edited by Kambadur Muralidhar, Amit Ghosh Ashok Kumar Singhvi. Indian National Science Academy, 2019. ISBN : 978-81-939482-1-7.
3. Anderson B.H., Dursaton, and Poole M.: Thesis and assignment writing, Wiley Eastern 1997.
4. Bijorn Gustavii: How to write and illustrate scientific papers? Cambridge University Press.
5. Bordens K.S. and Abbott, B.b.: Research Design and Methods, Mc Graw Hill, 2008.
6. Graziano, A., M., and Raulin, M.,L.: Research Methods – A Process of Inquiry, Sixth
7. Edition, Pearson, 2007.
8. IPR, MoU & MoA policies of Pondicherry University

DGET911: BIOENERGY AND BIO-PHOTONICS

Contact Hours: 45 Hours

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: Instrumental methods **[**10]

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

Unit II: Photosynthesis **[**10]

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

Unit III: Biomass **[**6]

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

Unit IV: Bioenergy conversion systems **[**10]

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

Unit V: Biodegradation & Microbial conversion **[**9]

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

Text Books:

1. Spectroscopy for Biological Sciences by Gordon G. Hammes, Wiley Interscience, John Wiley & Sons, 2005.
2. Introduction to Biophotonics by P.N.Prasad, Wiley Interscience, John Wiley & Sons, 2003.

References:

1. Lehninger's Principles of Biochemistry by David L. Nelson and Michael M. Cox, Macmillan Worth publisher.
2. Biomass Assessment Handbook - Bioenergy for a sustainable environment Edited by Frank Rosillo-Calle, Sarah Hemstock, Peter de Groot and Jeremy Woods, Earthscan November 2006.
3. Biomass Assessment Handbook - Bioenergy for a sustainable environment, Edited by Frank Rosillo-Calle, Sarah Hemstock, Peter de Groot and Jeremy Woods, Earthscan November 2006.
4. Success & Visions for Bioenergy: Thermal processing of biomass for bioenergy, biofuels and bioproducts, Edited by A V Bridgwater, CPL Press September 2007.

DGET 912: BIOENERGY AND CONVERSION SYSTEMS

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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.

References:

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.

DGET913: SOLAR THERMAL ENERGY: FUNDAMENTALS, DEVICES AND SYSTEMS

Contact Hours: 45

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

Unit I: Solar Radiation Geometry [7]

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

Unit II: Solar Collectors: Thermal Analysis [10]

Flat plate collectors: Effective energy losses; thermal analysis; heat capacity effect; overall loss coefficient; collector efficiency factor; collector heat removal factor; efficiency of flat plate collectors; testing methods. Evacuated tube collectors: Types; thermal analysis; testing methods.

Concentrating collectors: Designing and types; acceptance angle; geometric concentration ratio; optical efficiency; thermal efficiency; testing methods. Selective surfaces

Unit III: Solar Thermal Energy Storage [8]

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

Thermo-chemical storage: Materials; merits and demerits of thermo-chemical storage; potential of thermo-chemical storage materials for high temperature applications.

Unit IV: Solar thermal energy systems [12]

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

Unit V: Economic analysis for solar thermal engineering projects [8]

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. J.S. Hsieh, Solar Energy, Prentice Hall Inc. New Jerssey

References:

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

DGET914: NANOMATERIALS: PROPERTIES, SYNTHESIS, CHARACTERIZATION AND APPLICATIONS

Contact Hours: 45 Hours

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.

References:

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.

DGET915: ELECTROCHEMICAL ENERGY CONVERSION AND STORAGE

Contact Hours: 45

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.

References:

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.

DGET916: MODELLING AND SIMULATIONS OF GREEN ENERGY SYSTEMS

Contact Hours: 45

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

References:

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

DGET917: NANOTECHNOLOGY FOR ENERGY SYSTEMS

Contact Hours: 45

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]

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

Unit II: Physical Properties of Nanosystems [9]

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

Unit III: Nanotechnology for Photovoltaic Energy Conversion [9]

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

Unit IV: Nanotechnology for Photoelectrochemical and Photothermal Conversion Cells [9]

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

Unit V: Energy Efficient Nanodevices [9]

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

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

DGET918: SOLAR PHOTOVOLTAIC ENERGY CONVERSION

Contact Hours: 45

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: Properties of Semiconductor [9]

Semiconductors - crystals structures, atomic bonding, energy band 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, multijunction solar cells- Fabrication techniques: Diffusion, thin film technology- physical vapour deposition (PVD)- Electro-deposition-Molecular beam epitaxy (MBE)- Metal organic chemical vapour deposition (MOCVD)- Plasma enhanced chemical vapour deposition (PECVD)- Organic and Nano tech solar cells – contact & grid 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 – Thermophotovoltaic 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

References:

1. Solar Cells and their Applications, Larry D Partain (ed.), John Wiley and Sons, Inc, New York, 1995.
2. J. Nelson, The physics of solar cells, Imperial College Press, 2006.
3. Photovoltaic Materials, Richard H Bube, Imperial College Press, 1998
4. Practical Photovoltaics: Electricity from Solar Cells, by Richard Komp, ISBN:9780937948118, Publisher:Aatec Publications, Publication Date:February 2002.
5. Fundamentals of Photovoltaic Modules & Their Applications, by Gopal Nath Tiwari, ISBN:9781849730204, Publisher: Royal Society of Chemistry, 2010.
6. Solar Cells: Operating principles, Technology and Systems Applications, Martin Green, UNSW, Australia, 1997.

DGET919: ALGAL ENERGY TECHNOLOGY

45 hours Soft-core

Course outcome

- Attain knowledge on fundamental of Algal production.
- Acquire insight about the value added products of Algal resources.
- Understanding the tools and advancement in Algal engineering.

Unit I: Biomass to Energy 7 hours

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

Unit II: Macro algae and microalgae 10 hours

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

Unit III: Algae for biodiesel 8 hours

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

Unit IV: Chemical synthesis of biodiesel: 8 hours

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

Unit V: Conventional fuels versus biofuels 12 hours

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

Text books:

1. Freshwater Algae: Identification and Use as Bioindicators by Edward G. Bellinger and David C. Sigee, Wiley- Blackwell, John Wiley & Sons, 2010.
2. Resource Manual & Technical Manual, edited by S.Seshandri et al. A Bioresource Document compilation by Shri MurugappaChettiyar Research Centre, Sponsored by National Bioresoruce Development Board, DBT, India.

References:

1. Biodiesel Handling and Use Guide, Fourth Edition, an online document by National Renewable Energy Laboratory, USA. http://www.osti.gov/bridge
2. Algae by Linda E. Graham and Lee W. Wilcox, Prentice Hall, 2000.

DGET920: WIND ENERGY TECHNOLOGY

Contact Hours: 45

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 of Wind Turbines [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, and 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 and 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.
3. Spera D.A., Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, ASME Press, NY 1994

DGET921: SOLAR PHOTOVOLTAIC POWER SYSTEMS

45L

Course Outcome:

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.

References:

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.

DGET922: MICROBIAL TECHNOLOGY FOR BIOFUEL PRODUCTION

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 IV: 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, fermentor, types of fermentor, hybrid fermentor, sterilization, fermentation media, precursor and inhibitors, buffers, types of fermentation, upstream process, downstream process, troubleshooting mechanism.

Text books:

1. Handbook of Research on Bioenergy and Biomaterials, Consolidated and Green Processes, ISBN: 9781000210736, 1000210731, Apple Academic Press, 2021
2. Advances in Biofuels and Bioenergy, ISBN: 9781789232868, 1789232864, Intech Open, Editors: Jaya Soneji, Madhugiri Nageswara-Rao, 2018

References:

1. Varma, A., Kumara Behera, B. (2017). Microbial Biomass Process Technologies and Management. Germany: Springer International Publishing, ISBN: 9783319539133, 3319539132.
2. Microbial Resources for Sustainable Energy, Basanta Kumara Behera, Ajit Varma, Springer, 2016, ISBN: 3319337785, 9783319337784.

DGET923: COMPUTATIONAL FLUID DYNAMICS FOR ENERGY ENGINEERING

45L

Course outcome

- 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 behaviour 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 Systems [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

References:

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

DGET924: GREEN BUILDING AND SUSTAINABLE DEVELOPMENT

Contact Hours 45 Hours

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]

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, Environmental impact of building constructions. Environment friendly and cost-effective building technologies Energy rating of buildings and case studies

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

Framed Construction, Masonry Construction. Resources for Building Materials, Alternative concepts. Methods to reduce embodied energy in building materials: Use of local building materials, use of natural and renewable materials, Integration of renewable sources in buildings

Unit III: Comforts in Building [10]

Thermal comfort in Buildings – Issues, Passive Cooling concepts, Heat transfer, Characteristic of Building Materials and Building Techniques. Incidence of Solar Heat on Buildings-Implications of Geographical Locations, integration of emerging technologies. Energy efficient building envelopes, efficient lighting technologies, energy efficient appliances for heating and air conditioning systems, Daylighting, air ventilation, exhaust 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 and Technologies. New Age International, 2007.
2. Low Energy Cooling For Sustainable Buildings. John Wiley and Sons Ltd, 2009.

References:

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.
5. Michael F. Ashby Materials and the Environment, Elsevier, 2009
6. Jerry Yudelson Green building Through Integrated Design. McGraw Hill, 2009.

DGET925: ARTIFICIAL INTELLIGENCE, MACHINE LEARNING AND DATA ANALYSIS FOR PHOTOVOLTAIC SYSTEMS

45 Hours

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

References:

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

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DGET926: ANAEROBIC DIGESTION AND BIOGAS TECHNOLOGY

Contact Hours 45 Hours

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.

References:

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

DGET927: BIOPROSPECTING TECHNOLOGY FOR BIOFUEL PRODUCTION

Contact Hours 45 Hours

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. 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

References:

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,
3. 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
4. Nikalje, Anna. (2017). A Handbook of Chromatography.

DGET928: MICRO HYDROPOWER ENERGY SYSTEM

Contact Hours 45 Hours

Course outcome

After completion of the syllabus student able to: Know the basic components of a Micro Hydropower System, and how to design a MHP System, able to select the suitable system components. Able to know how to transmit the power, know how 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 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 book:

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

References:

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.

DGET929: ALTERNATE MATERIALS FOR SUSTAINABLE TECHNOLOGY

Contact Hours 45 Hours

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 harvesting materials. To expose the students to:

- Concepts of sustainability in construction materials
- Sustainable practices and green buildings
- Selecting materials and building elements
- Construction on the basis of sustainability and greenness

Unit I: Introduction [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 3.

References

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. Minsitry of Power, Energy Conservation Building Code 2007, Revised Version, Bureau of Energy Efficiency, 2008.
5. Architectural Energy Corporation, Building Envelope Stringency Analysis, International Institute for Energy Conservation, 2004.
6. Indian Building Congress, Practical Handbook on Energy Conservation in Buildings, 1st ed. Nabhi Publication, 2008.

DGET930: CARBON SEQUESTRATION AT THE LANDSCAPE LEVEL

Contact Hours 45 Hours

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.

DGET931: BIOPROCESS ENGINEERING FOR BIOFUELS

Contact Hours
45

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.

DGET932: ADVANCE MATERIALS FOR RENEWABLE ENERGY SYSTEMS

Contact Hours 45 Hours

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.
3. Composite Materials, Author by Deborah D.L.Chung, Springer, 2002.

References:

1. Advanced Materials for Sustainable Energy and a Greener Environment, ChemSusChem 4(10):1327-31, 2011.
2. Advanced Materials for Energy and Environmental Applications, Sunghoon Park, MDPI, 2022.
3. Wind energy –Hand book (2nd Edition), John Wiley & Sons, Authors-Tony Burton, Nick Jenkins, David Sharpe, Ervin Bossanyi, 2011.
4. Nanostructured Conductive Polymers, Editor. Ali Eftekhari, Wiley, 2010.
5. Organic Photovoltaics, CRC press-Taylor & Francis, Edited by Sam-Shajing Sun, Niyazi Serdar Sariciftci, 2005.

DGET933: INDUSTRIAL ENERGY AUDIT AND MANAGEMENT

Contact Hours 45 Hours

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

DGET934: ADVANCED BATTERY AND FUEL CELL TECHNOLOGIES

Contact Hours 45

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: Lead acid Battery [09]

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 [09]

Advanced anodes and cathodes – theoretical capacity – merits and demerits - Nanomaterials for anodes: carbon nanotubes, graphene, Sn, Al, Si, SnO_2, NiO, TiO_2 & $LiTiO_4$. 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 [09]

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 [09]

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 [09]

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.

DGET935: ELECTRIC VEHICLE TECHNOLOGY

Contact Hours 45 Hours

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 [09]

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.

Unt II: Electric Vehicles & Architectures [09]

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 [09]

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 [09]

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 [09]

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

References:

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.

DGET936: ADVANCED WIND ENERGY CONVERSION SYSTEM

Contact Hours 45 Hours

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 modeling – 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.

Textbooks

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.
3. Freris L.L., "Wind Energy Conversion Systems", Prentice Hall, 1990.

References

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

DGET937: BOREFINERIES

Contact Hours 45 Hours

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.

References:

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 bookcompany.
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

DGET938: BIOMASS FEEDSTOCK AND SOLID BIOFUEL PRODUCTION

Contact Hours 45 Hours

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: Resource Assessment of Biomass: [8]

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 II: Processing of Biomass: [7]

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 III: Solid Biofuel Production Processes: [8]

Pelleting and briquetting of solid biomass – Process flow – factors influencing heat values. Pretreatment of biomass for energy enhancement – Torrefaction, 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 IV: Energy Economy of solid biofuel: [7]

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 ZygmuntDrzymała, 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
7. Eriksson S. and M. Prior, The briquetting of Agricultural wastes for fuel, FAO Energy and Environment paper,1990

DGET939: BIO INDUSTRIAL SKILLS

Contact Hours 45 Hours

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

References:

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.

DGET940: GREEN CHEMICAL TECHNOLOGIES

Contact Hours 45 Hours

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

References:

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.

DGET941: ORGANIC PHOTOVOLTAICS

Contact Hours 45 Hours

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.

References:

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

DGET942: SUSTAINABLE TECHNOLOGIES FOR VALORISATION OF WASTE CARBON FEEDSTOCKS

Contact Hours 45 Hours

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 CO_2 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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