

# **M.Phil. / Ph.D. Course Work Syllabus**

**(For the candidates admitted from the academic year  
2022-2023 onwards)**



**DEPARTMENT OF  
ENERGY SCIENCE AND TECHNOLOGY  
SCHOOL OF ENERGY AND ENVIRONMENTAL SCIENCES  
PERIYAR UNIVERSITY**

(Accredited with “A<sup>++</sup>” Grade by the NAAC)

**PERIYAR PALKALAI NAGAR  
SALEM – 636 011  
TAMIL NADU**

**Eligibility for M.Phil. / Ph.D. in Energy Science**

Candidate who has passed the M.Sc. degree in Energy /Physics/ Chemistry/ Electronics/ Biotechnology/ Biochemistry/ Mathematics/ Nano Science of this University or any other University shall be eligible for admission to M.Phil. / Ph.D. degree of this University

**Eligibility for Ph.D. in Energy Technology**

Candidate who has passed the M.E/M.Tech degree in Aeronautical/Agricultural/ Automobile/ Chemical Engineering/ Civil/ Electrical/ Electronics/ Energy and Environment/ Instrumentation/ Mechanical/ Mechatronics/ Nano Technology of this University or any other University shall be eligible for admission to Ph.D degree of this University.

**Regulations**

As per the University norms

**STRUCTURE OF THE COURSE****PART-A**

Course	Code	Name	Total Marks
1	22UPESTR01	Research Methodology	100 Marks
2	22RPE01	Research and Publication Ethics (Common Syllabus Prescribed by UGC)	100 Marks
3	22UPESTR02	General Aspects of Energy Resources and Conversion Techniques (Common Course Subject Area)	100 Marks
4	22UPESTR03	Specialization Course	100 Marks
Part - B			
5	22UPESTR04	Specialized research Area	100 Marks

**Part-A****Course 4: List of Specialization Course**

<b>Course</b>	<b>Code</b>	<b>Name</b>	<b>Total Marks</b>
1	<b>22UPESTR03-1</b>	Solar energy technologies	Any one paper 100 Marks
2	<b>22UPESTR03-2</b>	Wind energy systems	
3	<b>22UPESTR03-3</b>	Bio energy Technologies	
4	<b>22UPESTR03-4</b>	Nanotechnology for energy systems	
5	<b>22UPESTR03-5</b>	Power electronics for renewable energy systems	
6	<b>22UPESTR03-6</b>	Hydrogen and fuel cells	
7	<b>22UPESTR03-7</b>	Computational fluid dynamics for energy systems	
8	<b>22UPESTR03-8</b>	Energy storage systems	
9	<b>22UPESTR03-9</b>	Advanced crystallography	
10	<b>22UPESTR03-10</b>	Thin film deposition technology	

**Question Paper Pattern for Course Work Examination**

<b>Course</b>	<b>Part-A</b>	<b>Question Paper Pattern</b>
1	<b>Research Methodology</b>	<p style="text-align: center;"><b>Section –A</b> 5X5= 25Marks (Either or Type)</p> <p style="text-align: center;"><b>Section – B</b> 5X10= 50 Marks (Either or Type)</p> <p><i>Note: The Examination will be Conducted for 75 Marks and will be converted into 100 Marks</i></p>
2	<b>Research and Publication Ethics</b> (Common Syllabus Prescribed by UGC)	
3	<b>General Aspects of Energy Resources and Conversion Techniques</b> (Common Course Subject Area)	
4	<b>Specialization Course</b>	
<b>Part - B</b>		
5	<b>Specialized Research Area</b>	<p style="text-align: center;"><b>Section-A</b> 5X8= 40 Marks (Either or Type)</p> <p style="text-align: center;"><b>Section-B</b> 5X12= 60 Marks (Either or Type)</p>

**Note:**

1. The Candidate provisionally registered for the Ph.D. degree with M.Sc. /M.E/ M.Tech should complete five course works. Four under Part-A and one Under Part-B at the end of first year
2. The candidate provisionally registered with M.Phil has to write two courses one under Part-A (Research and Publication Ethics) and one course under Part-B (Specialized Research Area) at the end of First Year.
3. The syllabus for the course-5 shall be framed by the concerned supervisor and approved by the doctoral committee.

**22UPESTR01****RESEARCH METHODOLOGY****COURSE OBJECTIVES**

- To learn and study the objective and various categories of research.
- To learn about problem identification and formulation.
- To learn about design of experiment.
- To learn about data collection, Analysis and interpretation.
- To acquire knowledge on report writing.

**UNIT – I : OBJECTIVES AND TYPES OF RESEARCH**

Motivation and objectives – Research methods vs Methodology. Types of research–Descriptive vs Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical.

**UNIT – II : RESEARCH FORMULATION**

Defining and formulating the research problem - Selecting the problem -Necessity of defining the problem - Importance of literature review in defining a problem – Literature review – Primary and secondary sources – reviews, treatise, monographs-patents – web as a source – searching the web - Critical literature review – Identifying gap areas from literature review - Development of working hypothesis.

**UNIT– III : RESEARCH DESIGN AND METHODS**

Research design – Basic Principles- Need of research design — Features of good design – Important concepts relating to research design – Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction, Development of Models. Developing a research plan - Exploration, Description, Diagnosis, and Experimentation. Determining experimental and sample designs.

**UNIT- IV : DATA COLLECTION AND ANALYSIS**

Execution of the research - Observation and Collection of data - Methods of data collection – Sampling Methods- Data Processing and Analysis strategies - Data Analysis with Statistical Packages - Hypothesis-testing - Generalization and Interpretation.

**UNIT – V : REPORTING AND THESIS WRITING**

Structure and components of scientific reports - Types of report – Technical reports and thesis – Significance – Different steps in the preparation – Layout, structure and Language of typical reports – Illustrations and tables -Bibliography, referencing and footnotes - Oral presentation – Planning – Preparation – Practice – Making presentation –Use of visual aids - Importance of effective communication – Plagiarism - Citation and acknowledgement- Reproducibility and accountability.

**COURSE OUTCOMES**

**Upon completion of this course, the students will be able to**

CO1	Distinguish various research methods.	K1-K6
CO2	Identify and formulate the research problem.	K1-K6
CO3	Design the experiments.	K1-K6
CO4	Collect data, analyze and interpret the data using various tools.	K1-K6
CO5	Write a report on research findings	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

**REFERENCE BOOKS**

1. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
2. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International.418p.
3. Sinha, S.C. and Dhiman, A.K., 2002. Research Methodology, Ess Ess publications. 2volumes.
4. Trochim, W.M.K., 2005. Research Methods: the concise knowledge base, Atomic Dog Publishing.270p.
5. Wadehra, B.L. 2000. Law relating to patents, trademarks, copyright designs and geographical indications. Universal Law Publishing.

**22RPE01****RESEARCH AND PUBLICATION ETHICS****THEORY****RPE 01: PHILOSOPHY AND ETHICS****3**

1. Introduction to philosophy: definition, nature and scope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgements and reactions

**RPE 02: SCIENTIFIC CONDUCT****5**

1. Ethics with respect to science and research
2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP)
4. Redundant publications: duplicate and overlapping publications, salami slicing Selective reporting and misrepresentation of data

**RPE 03: PUBLICATION ETHICS****7**

1. Publication ethics: definition, introduction and importance
2. Best practices I standards setting initiatives and guidelines: COPE, WAME, etc. 3. Conflicts of interest
3. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
4. Violation of publication ethics, authorship and contributor ship Identification of publication misconduct, complaints and appeals
5. Predatory publishers and journals

**PRACTICE****RPE 04: OPEN ACCESS PUBLISHING**

1. Open access publications and initiatives
2. SHERPA/ROMEO online resource to check publisher copyright & self-archiving policies
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder I journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

**RPE 05: PUBLICATION MISCONDUCT**

1. Group Discussions (2 hrs.)
2. Subject specific ethical issues, FFP, authorship
3. Conflicts of interest
4. Complaints and appeals: examples and fraud from India and abroad
5. Software tools (2 hrs.)
6. Use of plagiarism software like Turnitin, Urkund and other open source software tools

**RPE 06: DATABASES AND RESEARCH METRICS****Databases**

- Indexing databases
- Citation databases: Web of Science, Scopus, etc.

**Research Metrics**

- Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score
- Metrics: h-index, g index, i 10 index, altmetrics

## REFERENCE BOOKS

1. Bird, A. (2006). Philosophy of Science. Routledge.
2. Macintyre, Alasdair (1967) A Short History of Ethics. London.
3. P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN: 978- 9387480865
4. National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition. National Academies Press.
5. Resnik, D. B. (2011). What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1-10. Retrieved from [https://www.niehs.nih.gov/research/resources/bioethics/ what is /index. cfm](https://www.niehs.nih.gov/research/resources/bioethics/what_is/index.cfm) Beall,J.(2012).Predatory publishers are corrupting open access. Nature, 489(741 5), 179-179.
6. [https://doi.org/10 .1 038/489179a](https://doi.org/10.1038/489179a)
7. Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance (201 9), ISBN :978-8 1-939482- 1 -7 . [http ://www .insaindia .rcs.in/pdf/Ethics Book .pdf](http://www.insaindia.rcs.in/pdf/Ethics_Book.pdf)



**2UPESTR02****GENERAL ASPECTS OF ENERGY RESOURCES AND  
CONVERSION TECHNIQUES****COURSE OBJECTIVES**

- To study the energy scenario.
- To study the various energy conversion system.
- To learn about various solar energy conversion techniques.
- To learn wind energy systems.
- To know about other renewable energy sources.

**UNIT – I : GLOBAL AND INDIAN ENERGY SCENARIO**

Role of energy in economic development and social transformation - Energy sources - overall Energy demand and availability - Energy consumption in various sectors and its changing pattern - Depletion of energy sources- Need for use of new and renewable energy sources-present status and future of nuclear and renewable energy

**UNIT – II : SOLAR ENERGY**

Solar radiation at the earth's surface –solar radiation measurements – estimation of average solar radiation - solar thermal flat plate collectors - concentrating collectors – solar thermal applications - heating, cooling, desalination, drying, cooking– solar thermal electric power plant - principle of photovoltaic conversion of solar energy-types of solar cells - Photovoltaic applications: battery charger, domestic lighting, street lighting, water pumping- solar PV power plant–Net metering concept

**UNIT– III : WIND ENERGY**

Nature of the wind – power in the wind – factors influencing wind – wind data and energy estimation - wind speed monitoring - wind resource assessment -Betz limit - site selection - wind energy conversion devices - classification, characteristics, applications – offshore wind energy - Hybrid systems - safety and environmental aspects – wind energy potential and installation in India – Repowering concept.

**UNIT- IV : OTHER TYPES OF ENERGY**

Biomass resources and their classification - Biomass conversion processes – thermo-chemical conversion-bio diesel production – urban waste to energy conversion -ocean energy resources - principle of ocean thermal energy conversion (OTEC) - ocean thermal power plants - ocean wave energy conversion - tidal energy conversion – small hydro - geothermal energy - geothermal power plants – hydrogen production and storage- Fuel cell – principle of working-various types-construction and applications.

**UNIT – V : DIRECT CONVERSION OF THERMAL TO ELECTRICAL ENERGY**

Conventional energy conversion cycles - Reversible and irreversible cycles –Thermodynamics analysis of Carnot – Stirling – Ericsson – Otto – Diesel – Dual– Lenoir – Atkinson – Brayton – Rankine- Thermoelectric Converters – Thermionic converters – MHD – Ferro electric converter – Nernst effect generator

**COURSE OUTCOMES**

**Upon completion of this course, the students will be able to**

CO1	Understand the current energy scenario of global as well as India.	K1-K6
CO2	Knowing various methods of energy conversion techniques.	K1-K6
CO3	Understand solar energy and conversion techniques.	K1-K6
CO4	Aware about wind energy systems.	K1-K6

CO5	Understand the various renewable energy sources.	K1-K6
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**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

#### REFERENCE BOOKS

1. J. Goldemberg, T.B. Johansson, A.K.N. Reddy and R.H. Williams: Energy for a Sustainable World, Wiley Eastern,1990.
2. World Energy Resources : Charles E. Brown, Springer,2002.
3. Sukhatme, S.P., Solar Energy, Tata McGraw Hill,1984.
4. Twidell, J.W. and Weir, A., Renewable Energy Sources, EFN Spon Ltd.,1986.
5. Kishore VVN, Renewable Energy Engineering and Technology, Teri Press, New Delhi,2012.

## **PART-A**

### **SPECIALIZATION COURSE**

**22UPESTR03-1**

**SOLAR ENERGY TECHNOLOGIES**

#### **COURSE OBJECTIVES**

- To learn and study the solar energy, radiation and estimation.
- To study the various solar thermal energy technologies and their applications
- To learn about various solar Photovoltaic effect materials and conversion techniques
- To learn different kinds of solar energy observed materials
- To know about various solar collectors and solar cell techniques

#### **UNIT – I: INTRODUCTION**

Basics of solar energy - Blackbody radiation- Relation between radiation field energy density and radiation spectrum - Planck's formula in energy unit - Maximum spectral density - Planck's formula in wavelength unit - Wien displacement law - Stefan - Boltzmann law - Photoelectric effect - Einstein's theory of photons - Einstein's derivation of the black-body formula.

#### **UNIT – II: SOLAR RADIATION MEASUREMENT AND ESTIMATION**

Measurement of solar radiation - Solar energy measuring instruments – Pyranometer – Pyrliometer – Sunshine recorder - Estimation of average solar radiation - Ratio of beam and total radiation on tilted surface of that on horizontal surface.- Radiation Processing - Long Term- Evaluation of the Apparent Sunrise and Sunset Angles- Estimation of Daily/Monthly Average daily Tilt Factor Under Terrestrial Conditions

#### **UNIT-III: SOLAR PHOTOVOLTAIC POWER GENERATION**

Solar PV technologies overview - Stationary and concentrated PV - Inverter and control technologies - Master slave inverter system design - Standalone systems - Grid connected systems - Hybridization, synchronization and power evacuation - Site selection and land requirements - Techno-economic analysis of solar PV power plants - Environmental considerations.

#### **UNIT-IV: MATERIALS FOR SOLAR COLLECTORS AND SOLAR CELLS COLLECTOR**

Materials for Low, Medium and High Temperature Applications - Glazing Materials, Optical Materials - Absorber Coatings, Insulations, Desiccants, Use of Plastics - Reliability and Durability of Solar Collectors - Environmental Degradation of Low Cost Solar Collectors. Silicon, Cadmium Telluride, Gallium-Arsenic, GaInP / GaAs / Ge - Thin Film, Single Crystalline, Polycrystalline Materials - Multi Junction and Tandem Junction Solar Cells - Low Cost and High Efficiency Materials - Conversion Efficiency of Solar Cells.

#### **UNIT – V: THERMAL AND ELECTRICAL ENERGY STORAGE MATERIALS**

Thermal Storage Concepts - Materials for Sensible and Latent Heat Energy Storage. Organic, Inorganic Eutectic Materials, Materials for Low and High Temperature Storage Applications. Chemical storage Concepts - Rechargeable Batteries – Types, Operating range, Comparison and suitability for various applications - Super Capacitors.

**COURSE OUTCOME**

**Upon completion of this course, the students will be able to**

CO1	Qualitatively and quantitatively analyse solar energy and radiation	K1-K6
CO2	Knowing various solar thermal energy technologies and their applications	K1-K6
CO3	Understand solar Photovoltaic effect and conversion techniques	K1-K6
CO4	Aware about different types of solar energy observed materials	K1-K6
CO5	Perform research and development collectors and solar cell techniques	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

**REFERENCE BOOKS**

1. Duffie, J.A., and Beckman, W.A. Solar Energy Thermal Process, John Wiley and Sons, New York, 2006.
2. CS Solanki: Solar Photovoltaics – Fundamentals, Technologies and Applications, PHI Learning Pvt. Ltd., 2011.
3. Sukhatme and Nayak , Solar Energy: Principles Of Thermal Collection & Storage, Tata McGraw-Hill, 2008.
4. Nelson, J, The Physics of Solar Cells, Imperial College Press, 2003.
5. Jef Poortmans and Vladimir Arkhipov, Thin Film Solar Cells, John Wiley and Sons, 2008. Thomas Markvart, Solar Electricity, John Wiley and Sons, 2007.

**22UPESTR03-2****WIND ENERGY SYSTEMS****COURSE OBJECTIVES**

- To understand the fundamentals of wind energy and its conversion system
- To impart knowledge on air foil design and braking system
- To learn gear coupled generator wind turbine components
- To brief on the working of different generators and power conditioning system used in grid tied wind systems
- To impart knowledge on modern wind turbine control & monitoring

**UNIT – I: WIND ENERGY FUNDAMENTALS & WIND MEASUREMENTS**

Wind Energy Basics, Wind Speeds and scales, Terrain, Roughness, Wind Mechanics, Power Content, Class of wind turbines, Atmospheric Boundary Layers, Turbulence. Instrumentation for wind measurements, Wind data analysis, tabulation, Wind resource estimation, Betz's Limit, Turbulence Analysis

**UNIT – II: AERODYNAMICS THEORY & WIND TURBINE TYPES**

Airfoil terminology, Blade element theory, Blade design, Rotor performance and dynamics, Balancing technique (Rotor & Blade), Types of loads; Sources of loads Vertical Axis Type, Horizontal Axis, Constant Speed Constant Frequency, Variable speed Variable Frequency, Up Wind, Down Wind, Stall Control, Pitch Control, Gear Coupled Generator type, Direct Generator Drive /PMG/Rotor Excited Sync Generator

**UNIT-III: GEAR COUPLED GENERATOR WIND TURBINE COMPONENTS AND THEIR CONSTRUCTION**

Electronics Sensors /Encoder /Resolvers, Wind Measurement : Anemometer & Wind Vane, Grid Synchronisation System, Soft Starter, Switchgear [ACB/VCB], Transformer, Cables and assembly, Compensation Panel, Programmable Logic Control, UPS, Yaw & Pitch System : AC Drives, Safety Chain Circuits, Generator Rotor Resistor controller (Flexi Slip), Differential Protection Relay for Generator, Battery/Super Capacitor Charger & Batteries/ Super Capacitor for Pitch System, Transient Suppressor / Lightning Arrestors, Oscillation & Vibration sensing

**UNIT-IV: DIRECT ROTOR COUPLED GENERATOR (MULTIPOLE) [VARIABLE SPEED VARIABLE FREQ.]**

Excited Rotor Synch. Generator / PMG Generator, Control Rectifier, Capacitor Banks, Step Up / Boost Converter ( DC-DC Step Up), Grid Tied Inverter, Power Management, Grid Monitoring Unit (Voltage and Current), Transformer, Safety Chain Circuits

**UNIT – V: MODERN WIND TURBINE CONTROL & MONITORING SYSTEM**

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

**COURSE OUTCOMES**

**Upon completion of this course, the students will be able to**

CO1	Analyse the energy in conversion techniques of wind energy	K1-K6
CO2	Analyse the performance of wind turbine aerodynamics and braking system	K1-K6

CO3	Explain about various gear coupled generators with its construction	K1-K6
CO4	Explain about different types of generators and power condition used in wind systems	K1-K6
CO5	Analyse the concept of modern wind turbine control & monitoring	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

#### **REFERENCE BOOKS**

1. Freris, L.L., Wind Energy Conversion Systems, Prentice Hall, 1990
2. Kaldellis J.K, Stand – alone and Hybrid Wind Energy Systems, CRC Press, 2010
3. Mario Garcia –Sanz, Constantine H. Houppis, Wind Energy Systems, CRC Press 2012
4. Spera, D.A., Wind Turbine Technology: Fundamental concepts of Wind Turbine Engineering, ASME Press, 1994.
5. Twidell, J.W. and Weir, A., Renewable Energy Sources, EFN Spon Ltd., 1983

**22UPESTR03-3****BIO ENERGY TECHNOLOGIES****COURSE OBJECTIVES**

- To detail on the types of biomass, its surplus availability and characteristics.
- To create awareness on the technologies available for conversion of biomass to energy in terms of its technical competence and economic implications.
- To impart knowledge on stoichiometry and combustion of bio fuels
- To elucidate on the influence of equivalence ratio on thermochemical conversion of biomass
- To provide insight to the possibilities of producing liquid fuels form biomass

**UNIT – I: INTRODUCTION**

Biomass: types – advantages and drawbacks – Indian scenario – characteristics – carbon neutrality – conversion mechanisms – fuel assessment studies – densification technologies – Comparison with coal – Proximate & Ultimate Analysis - Thermo Gravimetric Analysis – Differential Thermal Analysis – Differential Scanning Calorimetry

**UNIT – II: BIOMETHANATION**

Microbial systems – phases in biogas production – parameters affecting gas production – effect of additives on biogas yield – possible feed stocks. Biogas plants – types – design – constructional details and comparison – biogas appliances – burner, luminaries and power generation – effect on engine performance

**UNIT-III: COMBUSTION**

Perfect, complete and incomplete combustion - stoichiometric air requirement for biofuels - equivalence ratio – fixed Bed and fluid Bed combustion – fuel and ash handling systems – steam cost comparison with conventional fuels

**UNIT-IV: GASIFICATION, PYROLYSIS AND CARBONISATION**

Chemistry of gasification - types – comparison – application – performance evaluation – economics – dual fuelling in IC engines – 100 % Gas Engines – engine characteristics on gas mode – gas cooling and cleaning systems - Pyrolysis - Classification - process governing parameters – Typical yield rates. Carbonization Techniques – merits of carbonized fuels

**UNIT – V: LIQUIFIED BIOFUELS**

History of usage of Straight Vegetable Oil (SVO) as fuel - Biodiesel production from oil seeds, waste oils and algae - Process and chemistry - Biodiesel health effects / emissions / performance. Production of alcoholic fuels (methanol and ethanol) from biomass – engine modifications

**COURSE OUTCOMES**

**Upon completion of this course, the students will be able to**

CO1	Estimate the surplus biomass availability of any given area	K1-K6
CO2	Design a biogas plant for a variety of biofuels	K1-K6
CO3	Determine and compare the cost of steam generation from biofuels with that of coal and petroleum fuels	K1-K6
CO4	Analyse the influence of process governing parameters in thermochemical	K1-K6

	conversion of biomass	
CO5	Synthesize liquid biofuels for power generation from biomass	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

#### **REFERENCE BOOKS**

1. Tom B Reed, Biomass Gasification – Principles and Technology, Noyce Data Corporation, 1981
2. David Boyles, Bio Energy Technology Thermodynamics and costs, Ellis Hoknood Chichester, 1984.
3. Khandelwal KC, Mahdi SS, Biogas Technology – A Practical Handbook, Tata McGraw Hill, 1986
4. Mahaeswari, R.C. Bio Energy for Rural Energisation, Concepts Publication,1997
5. Best Practises Manual for Biomass Briquetting, I R E D A, 1997



**22UPESTR03-4****NANOTECHNOLOGY FOR ENERGY SYSTEMS****COURSE OBJECTIVES**

- To learn and study the basics and scale of nanotechnology.
- To study the Factors nanomaterials and classification.
- To learn about various synthesis of nanomaterials technique.
- To learn importance and analysis of properties of nanomaterials.
- To know about conditions for the fabrication and characterization of nanostructures

**UNIT – I: BASICS AND SCALE OF NANOTECHNOLOGY**

Introduction and scientific revolutions-Time and length scale in structures -Definition of a nano system Dimensionality and size dependent phenomena -Surface to volume ratio -Fraction of surface atoms and surface energy -Surface stress and surface defects -Properties at nanoscale – optical & mechanical -Properties at nanoscale – electronic & magnetic

**UNIT – II: II NANOMATERIALS OF ENERGY SYSTEMS CLASSIFICATION**

Classification based on dimensionality -Quantum dots- wells and wires -Carbon-based nano materials – fullerenes and buckyballs-Carbon nanotubes and graphene - Metal based nano materials – Nanogold and Nanosilver -Metal oxide based nano materials -Nanocomposites and nanopolymers -Nanoglasses and nano ceramics -Biological nanomaterials

**UNIT-III: III SYNTHESIS OF NANOMATERIALS**

Chemical methods: Metal nanocrystals by reduction- Sol-Gel Process -Template Process -Solvothermal synthesis and photochemical synthesis -Sonochemical routes and chemical vapor deposition -Metal oxide chemical vapor deposition (MOCVD) Physical methods: Ball milling - Electrodeposition techniques- Inert Gas Condensation Technique (IGCT) – Thermal evaporation – Pulsed Laser Deposition (PLD) -Spray pyrolysis and flame pyrolysis -DC/RF magnetron sputtering, Molecular beam epitaxy (MBE)

**UNIT-IV: PROPERTIES OF NANOMATERIALS**

Elasticity-Strengths- Harnesses and Hall Petch Relationships in Nanomaterials-Melting point- Thermal conductivity- Specific heat- light absorption- color- light emission- Photoluminescence- Electroluminescence- Magneto optical effect–Resistivity- Thermoelectric Conversion Efficiency- Superconductivity -Magnetic Moment of Nanometre - Curie Temperature - magnetization and coercivity- magnetoresistance

**UNIT – V: FABRICATION AND CHARACTERIZATION OF NANOSTRUCTURES**

Nanofabrication: Photolithography and its limitation and electron beam lithography (EBL)-Nanoimprinting and soft lithography patterning Characterization: X-ray diffraction -Fourier transform infrared spectroscopy- Photoluminescence spectroscopy –Ultraviolet spectroscopy(UV)- Photoluminescence Spectroscopy(PL)- Nuclear Magnetic Resonance spectroscopy(NMR) -Atomic force Microscope(AFM) -Differential thermal analysis (DTA) -Field emission scanning electron microscopy (FESEM) and environmental scanning electron microscopy (ESEM)-High resolution transmission electron microscope (HRTEM)-X-ray photoelectron spectroscopy (XPS)

**COURSE OUTCOME**

**Upon completion of this course, the students will be able to**

CO1	Qualitatively and quantitatively analyse scale of nanotechnology.	K1-K6
CO2	Understand the nanomaterials and classification of technology	K1-K6
CO3	Knowing various synthesis of nanomaterials technique	K1-K6
CO4	Understand importance and analysis of properties of nanomaterials..	K1-K6
CO5	Gain the ability to perform research and development for the fabrication and characterization of nanostructures	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

**REFERENCE BOOKS**

1. T. Pradeep, "A Textbook of Nanoscience and Nanotechnology", Tata McGraw Hill Education Pvt. Ltd.,2012
2. Hari Singh Nalwa, "Nanostructured Materials and Nanotechnology", Academic Press, 2008
3. A.Nabok, "Organic and Inorganic Nanostructures", Artech House, 2009
4. C.Dupas, P.Houdy, M.Lahmani, "Nanoscience: Nanotechnologies and Nanophysics", Springer-Verlag Berlin Heidelberg, 2007
5. "Nanocrystals: Synthesis, Properties and Applications", C. N. R. Rao, P. J. Thomas and G. U. Kulkarni, Springer (2007).

22UPESTR03-5

## POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS

### COURSE OBJECTIVES

- To impart knowledge on conversion techniques and renewable energy technologies.
- To study the mechanisms of machines for the conversion of renewable energy sources.
- To learn the power converters and its applications in renewable energy systems.
- To understand the different conversion mechanisms of wind and solar systems.
- To understand the various hybrid systems of renewable energy conversion techniques.

### UNIT – I: INTRODUCTION

Environmental aspects of electric energy conversion: impacts of renewable energy generation on environment (cost-GHG Emission) - Qualitative study of different renewable energy resources: Solar, wind, ocean, Biomass, Fuel cell, Hydrogen energy systems and hybrid renewable energy systems

### UNIT – II: ELECTRICAL MACHINES FOR RENEWABLE ENERGY CONVERSION

Review of reference theory fundamentals-principle of operation and analysis: IG, PMSG, SCIG and DFIG

### UNIT-III: POWER CONVERTERS

Solar: Block diagram of solar photo voltaic system -Principle of operation: line commutated converters (inversion-mode) - Boost and buck-boost converters- selection Of inverter, battery sizing, array sizing Wind: three phase AC voltage controllers- AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters, Grid Interactive Inverters-matrix converters. Power Quality Measurements.

### UNIT-IV: ANALYSIS OF WIND AND PV SYSTEMS

Stand-alone operation of fixed and variable speed wind energy conversion systems and solar system- Grid connection Issues -Grid integrated PMSG and SCIG Based WECS Grid Integrated solar system

### UNIT – V: HYBRID RENEWABLE ENERGY SYSTEMS

Need for Hybrid Systems- Range and type of Hybrid systems- Case studies of Wind-PV Maximum Power Point Tracking (MPPT).

### COURSE OUTCOME

**Upon completion of this course, the students will be able to**

CO1	Analyse the various conversion techniques in renewable energy technologies.	K1-K6
CO2	Apply the various mechanisms for the conversion of renewable energy sources.	K1-K6
CO3	Identify the appropriate power converters for renewable energy systems.	K1-K6
CO4	Implement the different conversion mechanisms for wind and solar systems.	K1-K6
CO5	Recognize the importance of various hybrid renewable energy systems	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

### REFERENCE AND TEXT BOOKS

1. Leon Freris, David Infield, “Renewable energy in power systems”, John Wiley & Sons, 2008.
3. Rashid .M. H “power electronics Hand book”, Academic press, 2007.
4. Rai. G.D, “Non conventional energy sources”, Khanna publishes, 2010.

5. Ali Keyhani, Design of Smart Power Grid Renewable Energy Systems, John Wiley & Sons,2011.
6. Wind Electric Systems: S.N. Bhadra, D. Kasta, OXFORD university press, 2005

**22UPESTR03-6****HYDROGEN AND FUEL CELLS****COURSE OBJECTIVES**

- To study the basic production techniques of Hydrogen.
- To understand the concepts of various storage methods of Hydrogen.
- To study the thermodynamics and kinetics of fuel cell process.
- To understand the classifications, construction and working of fuel cells.
- To provide insights into fuel cell applications and its economics.

**UNIT – I: HYDROGEN – BASICS AND PRODUCTION TECHNIQUES**

Hydrogen – physical and chemical properties, salient characteristics. Production of hydrogen – steam reforming – water electrolysis – gasification and woody biomass conversion – biological hydrogen production – photo dissociation – direct thermal or catalytic splitting of water

**UNIT – II: HYDROGEN STORAGE AND APPLICATIONS**

Hydrogen storage options – compressed gas – liquid hydrogen – Hydride – chemical Storage – comparisons. Safety and management of hydrogen. Applications of Hydrogen.

**UNIT-III: INTRODUCTION TO FUEL CELLS**

History – principle - working - thermodynamics and kinetics of fuel cell process – performance evaluation of fuel cell – comparison on battery Vs fuel cell.

**UNIT-IV: CLASSIFICATION OF FUEL CELLS**

Types of fuel cells – AFC, PAFC, SOFC, MCFC, DMFC, PEMFC, MFC – principle, construction and working – relative merits and demerits.

**UNIT – V: FUEL CELL APPLICATIONS AND ECONOMICS**

Fuel cell usage for domestic power systems, large scale power generation, Automobile, Space. Economic and environmental analysis on usage of Hydrogen and Fuel cell. Future trends in fuel cells.

**COURSE OUTCOMES**

**Upon completion of this course, the students will be able to**

CO1	Analyze the techniques of Hydrogen generation.	K1-K6
CO2	Apply the various options for Hydrogen storage.	K1-K6
CO3	Recognize the principle operations of fuel cell, types, its thermodynamics and kinetics.	K1-K6
CO4	Comprehend the different types of fuel cells.	K1-K6
CO5	Apply the fuel cells for domestic, automotive, space craft power generations and evaluate the techno-economics of a fuel cells.	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

**REFERENCE BOOKS**

1. Barclay F.J., Fuel Cells, Engines and Hydrogen, Wiley, 2009.
2. Bent Sorensen (Sørensen), Hydrogen and Fuel Cells: Emerging Technologies and Applications, Elsevier, UK 2005.
3. Hart A.B. and G.J.Womack, Fuel Cells: Theory and Application, Prentice Hall, New York Ltd., London 1989.

4. Jeremy Rifkin, *The Hydrogen Economy*, Penguin Group, USA 2002.
5. Kordesch K. and G.Simader, *Fuel Cell and Their Applications*, Wiley-Vch, Germany 1996.

22UPESTR03-7

## COMPUTATIONAL FLUID DYNAMICS FOR ENERGY SYSTEMS

### COURSE OBJECTIVES

- To make students familiarize with the computational analysis
- To explain the numerical analysis of solving of steady and unsteady diffusion heat transfer
- To explain the numerical analysis of solving of convection-diffusion heat transfer
- To provide the details of discretization of incompressible flow governing equations
- To impart the knowledge of turbulence modelling

### UNIT – I: GOVERNING DIFFERENTIAL EQUATIONS AND DISCRETISATION TECHNIQUES

Basics of Heat Transfer, Fluid flow – Mathematical description of fluid flow and heat transfer – Conservation of mass, momentum, energy and chemical species - Classification of partial differential equations – Initial and Boundary Conditions – Discretisation techniques using finite difference methods – Taylor’s Series - Uniform and non-uniform Grids, Numerical Errors, Grid Independence Test.

### UNIT – II: DIFFUSION PROCESSES: FINITE VOLUME METHOD

Steady one-dimensional diffusion, Two and three dimensional steady state diffusion problems, Discretization of unsteady diffusion problems – Explicit, Implicit and Crank-Nicholson’s schemes, Stability of schemes.

### UNIT-III: CONVECTION - DIFFUSION PROCESSES: FINITE VOLUME METHOD

One dimensional convection – diffusion problem, Central difference scheme, upwind scheme – Hybrid and power law discretization techniques – QUICK scheme. – Assessment of discretization scheme properties.

### UNIT-IV: INCOMPRESSIBLE FLOW PROCESSES: FINITE VOLUME METHOD

Discretization of incompressible flow equations – Stream Function – Vortices methods - Pressure based algorithms, SIMPLE, SIMPLER, SIMPLEC & PISO algorithms.

### UNIT – V: TURBULENCE MODELLING

Kolmogorov’s Theory - Turbulence - Algebraic Models, One equation model &  $k - \epsilon$ ,  $k - \omega$  models - Standard and High and Low Reynolds number models

### COURSE OUTCOMES

**Upon completion of this course, the students will be able to**

CO1	Know the differences between various discretization techniques.	K1-K6
CO2	Learn the finite volume based numerical method for solving diffusion heat transfer problems.	K1-K6
CO3	Learn the finite volume based numerical method for solving convection-diffusion heat transfer problems.	K1-K6
CO4	Understand the discretization of incompressible flow governing equations	K1-K6
CO5	Recognize the impact of various turbulence modelling	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

**REFERENCE BOOKS**

1. Versteeg and Malalasekera, N, “An Introduction to computational Fluid Dynamics The Finite Volume Method,” Pearson Education, Ltd., Second Edition, 2014.
2. Anderson, D.A., Tannehill, J.I., and Pletcher, R.H., “Computational fluid Mechanics and Heat Transfer “ Hemisphere Publishing Corporation, New York, USA,1984
3. Subas, V.Patankar, “Numerical heat transfer fluid flow”, Hemisphere Publishing Corporation,1980.
4. Tapan K. Sengupta, “Fundamentals of Computational Fluid Dynamics” Universities Press, 2011.
5. Muralidhar, K., and Sundararajan, T., “Computational Fluid Flow and Heat Transfer”, Narosa Publishing House, New Delhi, 1995.



**22UPESTR03-8****ENERGY STORAGE SYSTEMS****COURSE OBJECTIVES**

- To understand the various types of energy storage technologies and its applications.
- To study the various modelling techniques of energy storage systems
- To learn the concepts and types of batteries.
- To make the students to get understand the concepts of Hydrogen storage.
- To provide the insights on Flywheel and compressed energy storage systems.

**UNIT – I: INTRODUCTION**

Necessity Of Energy Storage – Types Of Energy Storage – Comparison Of Energy Storage Technologies – Applications.

**UNIT – II: THERMAL ENERGY STORAGE SYSTEM**

Thermal Storage – Types – Modeling Of Thermal Storage Units – Simple Water and Rock Bed Storage System – Pressurized Water Storage System – Modeling Of Phase Change Storage System – Simple Units, Packed Bed Storage Units - Modeling Using Porous Medium Approach - Use Of Tran system.

**UNIT–III: ELECTRICAL ENERGY STORAGE SYSTEM**

Fundamental Concept of Batteries – Measuring Of Battery Performance, Charging and Discharging of a Battery, Storage Density, Energy Density, and Safety Issues. Types Of Batteries – Lead Acid, Nickel – Cadmium, Zinc Manganese Dioxide and Modern Batteries For Example (I) Zinc-Air (Ii) Nickel Hydride, (Iii) Lithium Battery.

**UNIT-IV: FUEL CELL**

Fuel Cell – History Of Fuel Cell, Principles Of Electrochemical Storage – Types – Hydrogen Oxygen Cells - Hydrogen Air Cell - Hydrocarbon Air Cell - Alkaline Fuel Cell - Detailed Analysis – Advantage And Drawback of Each Type.

**UNIT – V: ALTERNATE ENERGY STORAGE TECHNOLOGIES**

Flywheel, Super Capacitors, Principles & Methods – Applications, Compressed Air Energy Storage, Concept of Hybrid Storage – Applications.

**COURSE OUTCOME**

**Upon completion of this course, the students will be able to**

CO1	Identify the energy storage technologies for suitable applications.	K1-K6
CO2	Analyse the energy storage systems.	K1-K6
CO3	Recognize the concepts and types of batteries.	K1-K6
CO4	Diagnose the principle operations of Hydrogen energy storage.	K1-K6
CO5	Analyse the concepts of Flywheel and compressed energy storage system.	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

**REFERENCE BOOKS**

1. Ibrahim Dincer and Mark A. Rosen, “Thermal Energy Storage Systems and Applications”, John Wiley & Sons 2002.
2. James Larminie and Andrew Dicks, “Fuel Cell Systems Explained”, Wiley Publications, 2003.
3. Lunardini.V.J, Heat Transfer in Cold Climates, John Wiley and Sons 1981.
4. Ru-Shiliu, Leizhang and Xueliang Sun, “Electrochemical Technologies for Energy Storage and Conversion”, Wiley Publications, 2012.
5. Schmidt.F.W and Willmott.A.J, Thermal Storage and Regeneration, Hemisphere Publishing Corporation, 1981.

22UPESTR03-9

**ADVANCED CRYSTALLOGRAPHY**

L	T	P	C
4	0	0	4

**COURSE OBJECTIVES**

- To learn and study the Crystallography basic parameter and laws.
- To study the Factors and methods of crystallography technology.
- To learn about various Chemical analysis by diffraction technique.
- To learn importance and analysis of Crystallographic software.
- To know about conditions for Data collection of atoms in molecules.

**UNIT – I: INTRODUCTION**

Two-dimensional lattices -two-dimensional basis vectors and unit cells -Two-dimensional transformations between sets of-Basis vectors-Three-dimensional basis vectors, unit cells, and lattice transformations- X-ray radiation, X-ray diffraction- origin of X-ray radiation, synchrotron, Bragg's law- Ewald construction- Structure factor.

**UNIT – II: FACTORS OF CRYSTALLOGRAPHY**

crystallography- Symmetry operations- Direct and reciprocal lattice- rotation axis, inversion axis, glide planes, centrum of symmetry- International tables for Crystallography- Factors affecting the intensity of diffraction- absorption correction, Lp- correction, secondary extinction- Fourier transformation- Phase problem methods - Patterson synthesis, direct methods.

**UNIT-III: CHEMICAL ANALYSIS BY DIFFRACTION**

Hanawait method - Examples of qualitative analysis -Practical difficulties -Identification of surface deposits - Quantitative analysis (Single Phase) -Chemical analysis by parameter measurement -Quantitative analysis (Multiphase) -Direct comparison method -Internal standard method -Practical difficulties Absorption

**UNIT-IV: CRYSTALLOGRAPHIC SOFTWARE**

Crystallographic software, disorder, modulated structure, error analysis- Cambridge structural database, statistical treatment of structural data- quality, quantity, crystal structure from powder data-Huge facilities for structural analysis- Neutronography, spin density- neutron reactor, synchrotron, XFEL- sample requirements, magnetic structure, spin density- Interpretation of the structural results- interpretation and visualisation of the crystal structure, interpretation of publishes structural results.

**UNIT – V: DATA COLLECTION ATOMS IN MOLECULES**

Data collection of accurate structure factors for multipolar refinement- quality of single crystal, data collection at low temperature, error analysis Charge density analysis- AIM analysis- relation of the experimental and theoretical electronic structure and their correlation to chemical and physico-chemical properties

**COURSE OUTCOME**

**Upon completion of this course, the students will be able to**

CO1	Qualitatively and quantitatively analyse crystallography basic parameter and laws.	K1-K6
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CO2	To understand the Factors and methods of crystallography technology	K1-K6
CO3	Knowing various Chemical analysis by diffraction technique	K1-K6
CO4	Understand importance and analysis of Crystallographic software.	K1-K6
CO5	Perform research and development for the Crystallography	K1-K6

**K1- Remember, K2- Understand, K3- Apply , K4- Analyze, K5- evaluate and K6- Create**

## REFERENCE BOOKS

1. Giacobozzo, C. Fundamentals of Crystallography. Oxford : Oxford University Press, 1992. 654 p. ISBN 0-19-855579-2.
2. PAVELCIK, F -KUCHTA, Ľ. Difrakčne metódy. Bratislava : Univerzita Komenského v Bratislave, 1995. 159 p. ISBN 80-223-0892-7.
3. William D. Callister, Jr., Materials Science and Engineering: An Introduction, 7th Edition, John Wiley & Sons, (2006). (Chapter 3, 4 & 12).
4. Maureen M. Julian, Foundations of Crystallography, Taylor & Francis Group (2008)
5. Martin T. Dove, Structure and Dynamics-An atomic view of materials, Oxford University Press, (2003).

22UPESTR03-10

**THIN FILM DEPOSITION TECHNOLOGY**

L	T	P	C
4	0	0	4

**COURSE OBJECTIVES**

- To learn and study the Physical Vapor Deposition (PVD) thin film technology.
- To study the Chemical Vapor Deposition (CVD) thin film technology.
- To learn about various thin film spray deposition technique.
- To learn different kinds of thin film techniques.
- To know about conditions for the formation of thin films.

**UNIT – I: PHYSICAL VAPOR DEPOSITION (PVD)**

Introduction, vacuum pumps and systems, Physics and chemistry behind evaporation, film thickness, uniformity and purity, evaporation hardware and techniques; thermal, ebeam etc. sputtering; RF, DC, DC magnetron sputtering, hybrid and modified PVD processes, advantages of PVD, disadvantages of PVD.

**UNIT – II: CHEMICAL VAPOR DEPOSITION (CVD)**

Introduction, reaction types, thermodynamics of CVD, gas transport and growth kinetics, CVD process and basic systems; Low-Pressure CVD, Plasma-Enhanced CVD, Atmosphere-Pressure CVD, Metal-Organic CVD, advantages of CVD, disadvantages of CVD.

**UNIT-III: DEPOSITION TECHNIQUES**

Introduction, basic instrumentation, different type of spray techniques; spray pyrolysis technique, electrospray deposition technique, electro-spin deposition technique, spray printing, advantages and disadvantages of spray deposition techniques.

**UNIT-IV: OTHER TECHNIQUES**

Electroplating, Spin coating, Sol gel, Langmuir Blodgett (LB) Techniques, Epitaxial Film Growth, SILAR technique, Doctor blade technique etc. their introduction, basic instrumentation, varying parameters, their advantages and disadvantages.

**UNIT – V: CONDITIONS FOR THE FORMATION OF THIN FILMS**

Environment for thin film deposition, capillarity theory, Growth modes: zone model for sputtering and evaporation, Microstructure in thin films, adhesion, -Mechanical, electrical, and optical properties of thin films, few applications of thin films in various fields- Application to Renewable energy technology – Thin film solar cells, Quantum well and Quantum dot solar cells, dye – sensitized solar cells.

**COURSE OUTCOME**

**Upon completion of this course, the students will be able to**

CO1	Qualitatively and quantitatively, analyse Physical Vapour Deposition thin film technology.	K1-K6
CO2	Qualitatively and quantitatively, analyse Chemical Vapour Deposition thin film technology.	K1-K6
CO3	Knowing various thin film spray deposition technique	K1-K6
CO4	Understand different kinds of techniques about the thin film of techniques.	K1-K6
CO5	Perform research and development conditions for the formation of thin films.	K1-K6

**K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- evaluate and K6- Create**

**Reference Books**

1. The Material Science of thin films by Milton Ohring.
2. Coatings on Glass (volume 6) by H. K. Pulker.
3. Langmuir Blodgett films by C. W. Pitt, G. G. Roberts.
4. Handbook of thin film Technology by Frey, Hartmut, Khan and Hamid R.
5. Thin film Technology and Application by K. L. Chopra & L. K. Malhotra