DR. BABASAHEB AMBEDKAR MARATHWADA UNIVERSITY, CHHATRAPATI SAMBHAJINAGAR.

CIRCULAR NO.SU/Sci./University Deptt./NEP/18/2024

It is hereby inform to all concerned that, the syllabi prepared by the Departmental Committee and recommended by the Dean, Faculty of Science & Technology, Academic Council at its meeting held on 08 April 2024 has accepted the following Syllabi under the Faculty of Science & Technology **as per National Education Policy - 2020 run at University Department, Dr.Babasaheb Ambedkar Marathwada University, Chhatrapathi Sambhajinagar** as appended herewith.

Sr.No.	Courses	Semester
1.	**M.Sc.Botany**	**IIIrd & IVth Semester**
2.	**M.Sc.Forensic Science**	**IIIrd & IVth Semester**
3.	**M.Sc.Nanoscience & Technology**	**IIIrd & IVth Semester**

This is effective from the Academic Year 2024-25 and onwards.

All concerned are requested to note the contents of this circular and bring the notice to the students, teachers and staff for their information and necessary action.

University Campus,
Chhatrapati Sambhajinagar
- 431 004.
REF.NO.SU/NEP/2024/ 2401
Date:- 21.06.2024.

Deputy Registrar,
Academic Section

Copy forwarded with compliments to :-

1] **Head of the Department,** Dr.Babasaheb Ambedkar Marathwada University, Chhatrapati Sambhajinagar.
2] **The Director, University Network & Information Centre, UNIC**, with a request to upload this Circular on University Website.

Copy to :-

1] **The Director, Board of Examinations & Evaluation,** Dr.Babasaheb Ambedkar Marathwada University, Chhatrapati Sambhajinagar.
2] The Section Officer,[M.Sc.Unit] Examination Branch, Dr.Babasaheb Ambedkar Marathwada University, Chhatrapati Sambhajinagar.
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DR. BABASAHEB AMBEDKAR MARATHWADA UNIVERSITY, CHHATRAPATI SAMBHAJINAGAR

NAAC Re-accredited 'A' Grade

Department of Nanoscience and Technology

FACULTY OF SCIENCE & TECHNOLOGY

Two Years P.G. Programme in Nanoscience and Technology

(M. Sc. III and IV Semester)

As Per National Education Policy-2020

Course structure and Curriculum

(OBE with Choice Based Credit System)

Subject: Nanoscience and Technology

Effective From: 2024-25

02/08/2024

Head
Dept.of Nanoscience and Technology,
Dr. Babasaheb Ambedkar Marathwada University,
Chhatrapati Sambhajinagar-431004

Semester-III

Course Type	Course Code	Course Name	Teaching Scheme (Hrs./ week)		Credits Assigned		
			Theory	Practical	Theory	Practical	Total Credits
Major Mandatory DSC	NTTC-600	Advances in Energy Materials	2	-	2	-	8T
	NTTC -601	Fundamentals and Engineering of Solar Energy Devices	2	-	2	-	
	NTTC -602	Thin Films and Devices Fabrication	2	-	2	-	
	NTTC -603	Applied Surface Science	2	-	2		
	NTLC-604	Laboratory –VII	-	4	-	2	6L
	NTLC-605	Laboratory –VIII	-	4	-	2	
	NTLC-606	Laboratory –IX	-	4	-	2	
DSE* (Choose anytwo)	NTTE-607	Multiphysics Modelling	2	-	2	-	4T
	NTTE -608	MEMS and Micro-system Design	2	-	2	-	
	NTTE -609	Semiconductor Based Sensors	2	-	2	-	
	NTTE -610	Advanced Topics in Magnetic Nanomaterials	2	-	2	-	
Course Type: Research Project	NTRP-611	Research Project-I		8	-	4	4L
Total			**12**	**20**	**12**	**10**	**22**

*- **a)** Choice of DSE courses for offline mode is to the students subject to prior reporting of minimum ten students. b) Among the Four courses from DSE, one DSE is compulsory for offline mode and one among the remaining three for online (MOOC, NPTEL) mode. c) If online course for DSE is not available, studentsshould choose two courses for offline mode.

Course Code Nomenclature:
DSC-Discipline Specific Core, **DSE**- Discipline Specific Elective, **T**-Theory**,** **L**- Laboratory course, **NTTC**- Nanotechnology Theory Core, **NTLC**-Nanotechnology Laboratory Core, **NTTE**-Nanotechnology Theory Elective, **NTRM**- Nanotechnology Research Methodology, **NTOJT**-Nanotechnology on the Job Training, **NFTP**- Nanotechnology Field Project

	Semester: III	
Course Name: Advances in Energy Materials		Course Code: NTTC-600
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course explores the advanced materials utilized in the energy sector, focusing on their roles in energy production, conversion, storage, and efficiency. It delves into both renewable and non-renewable energy sources, emphasizing the sustainability and economic aspects of energy materials. Students will gain insights into the latest advancements in materials science and their applications in solving global energy challenges.

Prerequisites:

- Basic understanding of materials science and engineering principles
- Introductory knowledge of energy systems and environmental science
- Prior coursework in nanotechnology or related fields is recommended

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Analyze the global energy landscape and identify key energy security challenges.
- Understand the fundamental principles of energy materials production, processing, and sustainability.
- Evaluate the economics of energy materials and their global flow.
- Differentiate between various energy sources and materials used for energy harvesting.
- Explain the mechanisms and materials involved in energy conversion and storage technologies.
- Assess the role of materials in energy-saving applications and their importance in sustainable development.
- Identify the aging, damage, and failure mechanisms of materials in energy applications and propose solutions for their mitigation.

Course Outline:

Energy and environment: The global energy landscape and energy security
Materials energy fundamentals: Production, processing, and sustainability. Economics of energy materials. Global materials flow.
Energy Sources: Non-renewable and renewable energy sources. **Materials for energy harvesting**: Solar cells, nuclear materials, composites for wind energy, thermo-electrics.
Materials for energy conversion & storage: batteries, supercapacitors, hydrogen storage, photo-conversion, fuel cells, piezoelectrics, phase change materials
Materials for energy saving: Energy efficient transportation and housing applications (thermal insulation, transformers, actuators, generators, magnetocaloric/electrocaloric materials) Aging, damage, and failure of materials in energy harvesting, conversion, storage, and saving applications.

Suggested Books

1. D. S. Ginley, D. Cahen, Fundamentals of Materials for Energy and Environmental Sustainability: Cambridge University Press, Cambridge, 2011, ISBN 9781107000230.
2. R.C. Neville, Solar Energy Conversion, Elsevier, 1995, ISBN: 9780444898180.
3. C. C. Sorrell, J. Nowotny, S Sugihara, Materials for Energy Conversion Devices, Woodhead Publishing, 2005, ISBN: 9781855739321.
4. L. M. Fraas, and L.D. Partain, Solar Cells and Their Applications, John Wiley & Sons, 2010, ISBN: 97804704463314.

	Semester: III	
Course Name: Fundamentals and Engineering of Solar Energy Devices		**Course Code: NTTC-601**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

This course provides an in-depth exploration of the principles and engineering of solar energy devices, focusing on the working mechanisms of solar cells and their practical applications. Students will learn about the fundamental concepts of photoelectric conversion, various solar cell technologies, their characteristics, and the latest advancements in the field. The course also covers the challenges, potential hazards, and future prospects of photovoltaic technology.

Prerequisites:

- Basic knowledge of physics and chemistry
- Introductory coursework in materials science or nanotechnology
- Familiarity with semiconductor physics is beneficia

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Explain the working principles of solar cells and the fundamentals of photoelectric conversion.
- Analyze the efficiency and performance characteristics of different types of solar cells.
- Understand the various recombination processes and their impact on solar cell efficiency.
- Identify the key parameters affecting solar cell performance and how to optimize them.
- Compare the structures, advantages, and challenges of different generations of solar cells.
- Evaluate the potential hazards and safety considerations in solar energy applications.
- Discuss the current status and future prospects of photovoltaic technology and emerging solar cell technologies.

Course Outline:

Fundamentals and basics concepts: Working principle of solar cell, fundamental of photoelectric conversions (*charge excitation, conduction, separation, and collection*), Light absorption and reflections, Solar energy conversion (P*hotovoltaic, Solar thermal and photochemical*), Shockley–Queisser Limit (*Efficiency, Recombination time, AM1.5 radiation*), Generation and recombination of electron-hole pairs, recombination processes (*Radiative, Auger, Schokley-Read-Hall, direct/Langevin type, trap assisted, direct, interfacial, geminate, and non-geminate recombination*) and possible losses.

Characteristic: Equivalent circuits of the solar cell, Physical aspects of efficiency, Irradiation and series/shunt resistances on the open-circuit voltage (*Voc*) and short-circuit current (*Isc*), Dark and illuminated characteristics, Dark current, Light generated current, Effects of shading, Significance of various parameters (O*ut-put parameter, FF, solar cell η, Isc, Voc, Quantum efficiency, Maximum power point operation*), Antireflections coating, Practical efficiency limit (P*arasitic resistance, Losses in Isc, Voc, and FF, Effects of temperature, Series and shunt resistance, high irradiance*), Theoretical Limits, Challenges, and New Ideas.

Solar Cell Devices: Basic structure, modeling, advantages, disadvantages and challenges, Generations of solar cells, Si solar cell (*Single- and Poly- Crystalline, Amorphous, and Hybrid*), Thin film solar cells (*Amorphous silicon, Cd-Te, Cd-Se, CZTS, CIGS solar cells*), Grätzel & tandem cell(Metal-Oxide micro/nano-structures; *fabrication, Mechanism, Key efficiency parameters, Substrate effect, Examples of dyes for photosensitization, Electrolytes, Influence of additives on the performance,*), Heterojunction organic, Perovskite, Quantum dots and Hybrid solar cell (*types, materials used, compositions of components, processing, architectures, efficiency limits, stability issues, temperature effect*), Emerging new technologies.

Over view of potential hazards, Solar energy storage/utilization (*Batteries, Supercapacitor, Display devices, Emitters, and Generators etc.*), Status and prospective of *PV technology.*

Suggested Books:

1. A. McEvoy, T. Markvart, L. Castaner, **Solar Cells: Materials, Manufacture and Operation,** 2nd Edition, Elsevier, 2013, ISBN: 9780080993799.
2. T. Soga, **Nanostructured Materials for Solar Energy Conversion**, Elsevier, 2006, ISBN: 9780444528445.
3. D. Yogi Goswami, **Principles of Solar Engineering,** 3rd Edition, CRC Press, 2015, ISBN: 9781466563780.
4. A. L. Fahrenbruch, R. Bube, **Fundamentals of Solar Cells**, Elsevier, 1983, ISBN: 9780323145381.
5. C. J. Chen, **Physics of Solar Energy,** John Wiley & Sons, Inc., 2011, ISBN: 9780470647806.
6. P. Wurfel, **Physics of Solar Cells: From Basic Principles to Advanced Concepts,** 2nd Edition, Wiley-VCH, 2005, ISBN: 9783527408573.
7. L Fraas, L. Partain, **Solar Cells & Their Applications,** 2nd Edition, John Wiley & Sons, 2010, ISBN: 9780470446331.

	Semester: III	
Course Name: Thin Films and Devices Fabrication		Course Code: NTTC-602
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course provides a comprehensive understanding of thin film technology and its applications in device fabrication. It covers the fundamental principles of thin film formation, deposition techniques, and characterization methods. Students will gain practical knowledge in wafer processing, device fabrication, and the latest advancements in the microelectronics industry. The course includes hands-on laboratory work to reinforce theoretical concepts.

Prerequisites:

- Basic understanding of physics, chemistry, and materials science
- Introductory knowledge of semiconductor devices and fabrication techniques
- Prior coursework in nanotechnology or related fields is recommended

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Explain the fundamental principles of thin film formation and the physics, chemistry, and materials science involved.
- Identify and control key parameters affecting thin film deposition.
- Describe various thin film deposition techniques and their applications.
- Utilize advanced thin film characterization techniques to analyze film properties.
- Understand the principles and applications of Chemical Mechanical Polishing/Planarization (CMP) in semiconductor fabrication.
- Demonstrate knowledge of wafer processing and device fabrication techniques.
- Apply thin film deposition and characterization techniques in laboratory settings to fabricate and test devices such as gas sensors and UV sensors.
- Discuss current challenges and advancements in the microelectronics industry related to thin film technology.

Course Outline:

Introduction and Overview: Basic Physics, Chemistry and Materials science involved in Thin films fabrication

Steps in thin film formation: Thermal accommodation, binding, surface diffusion, nucleation, island growth, coalescence, etc.

Thin Controlling Parameters: Environment, Temperature, Concentration, etc.

Film Deposition: Vacuum and kinetic theory of gasses, Evaporation, Sputtered deposition, Cathodic Arc Deposition, Ion Beam, Molecular Beam, Wet chemical, Electrochemical, Hydrothermal, etc.

Thin Film Characterization: Imaging techniques, structural technique, chemical technique, optical technique, electrical/magnetic technique, mechanical technique.

Chemical Mechanical Polishing/Planarization (CMP): Chemical process and Mechanical process, working principals, Usage in semiconductor fabrication, Limitations of CMP, Applications, etc.

Wafer processing and Device fabrication: Wafer fabrication and processing - its importance in device fabrication, Introduction to lithography, Introduction to various electrode pattering and materials involved in electronic devices. Materials related probleM.S. and challenges ahead in microelectronics industry.

Laboratory work: Thin film deposition by various techniques; Characterizations by -X-ray diffraction pattern (XRD), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), Uv-Vis, Raman, etc.; device fabrications like -gas sensors, -UV sensors, etc.

Suggested Books

1) L I. Maissel and R. Glang, **Handbook of Thin Film Technology,** McGraw-Hill, 1970.

2) M. Ohring, **Materials Science of Thin FilM.S.**, Academic Press (2nd Edition) 2001, ISBN-13:978-0125249751.
3) J. L. Vossen and W. Kern, **Thin Film Processes,** Academic Press (January 11, 1979) ISBN-13:978-0127282503.
4) **M. H. Francombe, Handbook of Thin Film Devices,** Academic Press (Volume-I-V) 2000, ISBN: 978-0122653209.
5) Z. Cao, **Thin Film Growth: Physics, Materials Science and Applications,** Woodhead Publishing; 1 edition (August 1, 2011) ISBN-13: 978-1845697365.
6) F. C. Matacotta and G. Ottaviani, **Science and Technology of Thin FilM.S.,** World Scientific Publishing Co. 1995, ISBN: 978-9810221935.
7) S. Wolf, **Silicon processing for the VLSI Era — Vol. IV Deep-submicron Process Technology**, Lattice Press Publisher, 2002, ISBN 978-0-9616721-7-1, Chapter 8 "Chemical mechanical polishing" pp. 313.

	Semester: III	
Course Name: Applied Surface Science		Course Code: NTTC-603
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course explores the fundamental and applied aspects of surface science, focusing on the physical and chemical properties of surfaces and interfaces. Students will gain an understanding of surface free energy, surface tension, wettability, surface adhesion, and the thermodynamics and kinetics of adsorption and desorption. The course will cover atomic and electronic structures of surfaces, surface reactions, and methods for determining the composition and structure of surfaces and near-surface layers of materials. Emphasis will be placed on the practical applications of surface science in various fields such as catalysis, thin film growth, and surface characterization.

Prerequisites:

- Basic knowledge of physics and chemistry
- Introductory coursework in materials science or nanotechnology
- Familiarity with thermodynamics and kinetics

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Understand and explain the fundamental concepts of surface free energy, surface tension, wettability, and surface adhesion.
- Analyze the thermodynamics and kinetics of adsorption and desorption processes on surfaces.
- Describe the atomic and electronic structures of surfaces and their impact on surface properties.
- Discuss the role of non-thermal excitations and surface reactions in catalysis.
- Understand the vibrational and optical properties of surfaces and their applications.
- Explain the principles of liquid interfaces, growth, and epitaxy.
- Utilize various methods to determine the composition and structure of surfaces and near-surface layers.
- Apply surface science concepts to practical applications in materials science and engineering.

Course Outline:

Basic concepts & definitions; Surface free energy; Surface tension; Wettability, Surface adhesion; Thermodynamics and kinetics of adsorption & desorption; Surface diffusion kinetics; Atomic and electronic structure of surfaces; Non-thermal excitations of surfaces, catalysis and surface reactions; Vibrational and optical properties of surfaces; Liquid interfaces; Growth and Epitaxy; Methods for determining composition and structure of surfaces and near-surface layers of materials

Suggested Books

1. John B. Hudson, Surface Science: An Introduction, Elsevier Science & Technology, Oxford, United Kingdom, 1992, ISBN: 978-0-471-25239-9
2. H. Luth, Surfaces and Interfaces of Solids (2nd Ed.), Springer- Verlag Berlin Heidelberg, New York (USA), 1993, ISBN: 978-3- 662-10159-9
3. Andrew Zangwill, Physics at Surfaces, Cambridge University Press, Cambridge (UK), 1988, ISBN: 978-0-521-34752-5
4. M. Prutton, Introduction to Surface Physics, Clarendon Press, Gloucestershire (UK), 1994, ISBN: 978-0-198-53476-1
5. D. P. Woodruff and T. A. Delchar, Modern Techniques of Surface Science, 2nd Edition, Cambridge University Press, Cambridge (UK), 1994, ISBN: 978-0-521-42498-1
6. D. Brune, R. Hellborg, H. J. Whitlow, O. Hunderi, Surface Characterization: A User's Sourcebook, Wiley- VCH Verlag GmbH, Germany, 2007, ISBN: 978-3-527-61245-1

	Semester: III	
Course Name: Laboratory Course –VII, VIII and IX		Course Code: NTLC-604, 605, 606
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course provides hands-on experience with advanced experimental techniques in surface and thin film science. It covers the fundamental principles and practical applications of thin film deposition, surface characterization, and device fabrication. Students will engage in laboratory experiments that reinforce theoretical concepts and develop skills in using state-of-the-art equipment and methodologies. The course aims to prepare students for research and industry roles in nanotechnology, materials science, and related fields.

Prerequisites:

- Basic knowledge of physics, chemistry, and materials science
- Prior coursework in thin films, surface science, or nanotechnology
- Familiarity with laboratory safety and basic experimental techniques

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Perform thin film deposition using various techniques and understand the underlying principles.
- Utilize advanced characterization techniques to analyze thin film and surface properties.
- Fabricate and test devices such as sensors using thin film technologies.
- Apply thermodynamic and kinetic concepts to surface and thin film processes.
- Interpret experimental data and troubleshoot common issues in surface science and thin film fabrication.
- Students will get to know basic universal safety standards and practices in laboratories.

Course Outline:

List of open ended experiments:

NTLC-604:

1. Thin Film Deposition by Chemical Bath Deposition
2. Characterization of Thin Films using X-Ray Diffraction (XRD)
3. Surface Roughness Analysis using Atomic Force Microscopy (AFM)
4. Photovoltaic Device Fabrication
5. Contact Angle Measurement for Wettability:

NTLC-605:

1. Sputter Deposition of Thin Films.
2. Raman Spectroscopy for Chemical Characterization.
3. UV-Vis Spectroscopy for Optical Properties.
4. Fabrication of Gas Sensors
5. Electrochemical analysis of Deposited thin films.

NTLC-606:

1. Spin Coating of Thin Films
2. Scanning Electron Microscopy (SEM) Analysis
3. Fabrication of UV Sensors:
4. Electrochemical Deposition of Thin Films
5. Four-Point Probe Measurement for Electrical Conductivity.

	Semester: III	
Course Name: Multiphysics Modelling		Course Code: NTTE-607
Course type: DSE		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:
The "Multiphysics Modelling" course provides an in-depth exploration of continuum mechanics, thermo-elasticity, and heat transfer. It covers the fundamental principles and equations governing the behavior of materials and fluids under various physical phenomena, including mechanical, thermal, and electromagnetic interactions. The course delves into the mathematical modeling and analysis of stress, strain, and heat transfer mechanisms, emphasizing the integration of multiple physical processes for comprehensive problem-solving in engineering applications.

Prerequisites:
- Basic knowledge of mechanics and thermodynamics
- Familiarity with differential equations and linear algebra
- Understanding of basic principles in physics and materials science

Learning Outcomes (LO):
Upon successful completion of this course, students will be able to:
1. Understand and use basic principles of continuum mechanics.
2. Apply equations for continuity, momentum, and energy in physical systems.
3. Analyze thermo-elasticity problems and understand thermal stresses.
4. Solve problems involving the coupling of thermal, electrical, and mechanical effects.
5. Explain the modes of heat transfer: conduction, radiation, and convection.
6. Perform heat conduction analyses using fin approximations.
7. Use dimensionless numbers to solve convective heat transfer problems.
8. Identify and analyze different flow regimes in heat transfer scenarios.

Course Outline:

Introduction to continuum mechanics: REV; Cauchy Stress tensor; Strain tensor, strain rate, material and spatial derivatives; General principles, continuity equation, momentum and energy principles, mass-momentum and energy transport theorems;
Thermo-Elasticity: Classical elasticity, Generalized Hooke's law, isotropy, thermal stresses and strain, stress concentration, Boundary value problems, Introduction to thermo-Electromagneto-mechanical coupling: Joule effect, linear piezoelectricity, Maxwell stress tensor;
Heat Transfer: The three modes of heat transfer: conduction, radiation, convection. Phenomenological approach to the heat transfer coefficient: coupling between conduction and convection. Steady-state heat conduction. Fin approximation. Ideal and infinite fins. Unsteady conduction. Characteristic times and lengths, dimensional analysis, Fourier and Biot numbers. **Convective heat transfer:** Dimensional approach to forced convection. Notions of mechanical and thermal boundary layers. Reynolds, Prandtl and Nusselt numbers. Laminar-turbulent transition. Standard cases (tube, flat plate) of internal and external convection in the fully developed regime.

1. J.N. Reddy, **Principles of Continuum Mechanics**, Cambridge University Press; 1stEdition, 2010, ISBN:0521513693
2. J.G. Simmonds**, A brief on Tensor Analysis**, Springer, 1982, ISBN: 978-1-4419-8522-4
3. M. Kaviany, **Principles of Heat Transfer**, 2002,ISBN:9781468404128.
4. COM.S.OL Multiphysics Manual.

	Semester: III	
Course Name: MEMS and Micro-system Design		Course Code: NTTE-608
Course type: DSE		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:
The "MEMS and Micro-system Design" course offers a comprehensive introduction to the principles, design, and applications of Micro-Electro-Mechanical Systems (MEMS) and micro-systems. Students will explore the multidisciplinary nature of these technologies, their intrinsic characteristics, and their applications across various industries. The course covers the design and function of micro-sensors and micro-actuators, the materials and mechanics involved in micro-system fabrication, and practical case studies of MEMS products. This course provides a solid foundation for understanding and designing advanced micro-systems and their real-world applications.

Prerequisites:
- Basic understanding of physics and materials science
- Knowledge of electronics and mechanical engineering principles
- Familiarity with basic manufacturing processes and semiconductor devices

Learning Outcomes (LO):
Upon successful completion of this course, students will be able to:
1. Explain the basic concepts and multidisciplinary nature of MEMS and micro-systems.
2. Understand the principles of scaling laws in miniaturization and their implications.
3. Identify different types of micro-sensors and micro-actuators and their working principles.
4. Analyze the materials and mechanics involved in the design and fabrication of micro-systems.
5. Describe the process of micro-fabrication and micro-etching.
6. Understand the packaging and integration aspects of micro-systems.
7. Evaluate the application of MEMS and micro-systems in various industries.

Course Outline:
Introduction to MEMS and Micro-systems: Micro-electro-mechanical- systems (MEMS) and micro-system products, the multidisciplinary nature of micro-systems, scaling laws in miniaturization, application of micro system in other industries, intrinsic characteristics of MEMS.
Micro-actuators and Micro-sensors: Micro-sensors, acoustic wave sensors, biomedical and nano-sensors, chemical sensors, optical sensors, pressure sensors, thermal sensors, micro-actuation through thermal forces, SMA-Piezo electric crystals, and electrostatic forces, magnetic actuation, micro-grippers, micro-motors, micro-valves, micropumps, micro-accelerometers.
Materials, Mechanics and design of micro-systems: Silicon as a substrate, compounds, piezo-resisitors, polymers and packaging materials, micro-fabrication and micro-etching: static bending of thin plates, thermo mechanics and thin film mechanics.
Case studies of MEM.S. Products: Micro-fluidic devices, micro/nano transducers, blood pressure sensor, microphone-acceleration sensors, gyroscope, an overview of micro-system packaging.

Suggested Books:

1. Tai-Ran Hsu, **MEMS and Micro system Design and Manufacturing**, Tata McGraw Hill, ISBN 07-239391-2.
2. Chang Liu, **Foundation of MEM.S.**, Pearson Education, ISBN (978-81-317-6475-6)
3. Guozhong Cao,Ying, **Nanostructure and Nano materials, synthesis, properties and applications**, World Scientific Publishing Co. 2011
4. Robert Kelsall, Ian W.Hamley, Mark Geoghegan, **NanoScale Science and Technology**, ISBN 13:978047085086
5. Lifeng Chi, **Nano technology-Volume 8: Nanostructured surfaces**, Wiley Publication, ISBN13:9783527317394.

	Semester: III	
Course Name: Semiconductor Based Sensors		Course Code: NTTE-609
Course type: DSE		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course offers an in-depth exploration of semiconductor-based sensors, covering their classification, fabrication, and various applications. Students will gain a comprehensive understanding of the underlying principles, design considerations, and technological advancements in semiconductor sensors. Through theoretical and practical sessions, the course aims to equip students with the knowledge and skills required to design, fabricate, and characterize different types of semiconductor sensors used in various industries.

Prerequisites:

- Basic knowledge of semiconductor physics
- Prior coursework in electronics or materials science
- Familiarity with basic concepts in sensors and transducers

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Classify and describe various types of semiconductor sensors and their applications.
- Understand and apply the basic fabrication processes for semiconductor sensors.
- Design and analyze mechanical, thermal, magnetic, optical, chemical, and biosensors.
- Explain the interaction of gaseous species at semiconductor surfaces and its application in gas sensing.
- Integrate semiconductor sensors into systems and understand the interface electronics required.

Course Outline:

Introduction: Introduction and classification of sensors, sensors and transducers, Semiconductor sensors and their classification, sensor characterization, Evolution of semiconductor sensors.

Semiconductor Sensors Technologies: Introduction to basic fabrication processes, Micromechanical Process Design, Bulk Micromachining, surface micromachining, other manufacturing techniques, Applied Statistics & Probability in semiconductor manufacturing.

Mechanical Sensors: Piezoresistivity, and Piezoresistive sensors, Capacitive sensors, Piezoelectric materials and acoustic sensors, SAW based sensors, strain gauge and cantilever based sensors. Thermal sensors, Thermal sensing elements, Micro/Nanoelectromechanical sensors (MEMS/ NEMS).

Magnetic and Optical sensors: Integrated Hall sensors, magnetotransistors, photodiodes and phototransistors, HgCdTe based Infrared sensors, High energy photodiodes.

Chemical and Biosensors: Introduction to interaction of gaseous species at semiconductor surfaces, thin film-based sensors, Field Effect Transistor (FET) devices for gas/ ion sensing, Immobilization of enzymes in biosensors, Transduction principles and packaging on biosensors.

Integrated Sensors: Introduction, System Organization & Functions, Interface electronics, Examples of Integrated sensors.

Suggested Books:

1. Mohamed Gad-el-Hak, **The MEMS Handbook**, CRC Press (ISBN: 0-8493-0077-0).
2. S. M. Sze, **Semiconductor Sensors**, J. Wiley (ISBN: 978-0471546092).
3. R. Shinar and J. Shinar, **Organic Electronics in Sensors and Biotechnology**, Mc Graw Hill (ISBN: 978-0071596756).
4. J. W. Gardner, **Microsensors: Principles and Applications**, Wiley (ISBN: 978-0471941361).
5. S. Middelhoek, S. Audet, **Silicon Sensors**, Academic Press (ISBN: 0-12-495051-5).
6. R. F. Wolffenbuttel, **Silicon Sensors and Circuits: On Chip compatibility**, Chapman and Hall (ISBN: 0-412-70970-8).

	Semester: III	
Course Name: Advanced Topics in Magnetic Nanomaterials		Course Code: NTTE-610
Course type: DSE		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course delves into the advanced concepts and applications of magnetic nanomaterials, exploring their structural, magnetic, and electronic properties. Students will gain an understanding of various phenomena such as magnetism, superconductivity, and magnetoelectric effects, as well as the latest advancements in nanotechnology and spin electronics. The course aims to equip students with the knowledge to analyze and apply magnetic nanomaterials in cutting-edge research and technological innovations.

Prerequisites:

- Fundamental knowledge of solid-state physics
- Basic understanding of materials science and condensed matter physics
- Prior coursework in magnetism or related fields

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Explain the correlation between structural, magnetic, and electronic properties in magnetic nanomaterials.
- Analyze the principles of superconductivity and the properties of high-temperature superconductors.
- Understand and apply the concepts of dilute magnetic semiconductors and spin electronics.
- Describe the properties and applications of ferroelectric, multiferroic, and magnetoelectric materials.
- Discuss recent advancements and discoveries in the field of magnetic nanomaterials and related technologies.

Course Outline:

- Magnetism, correlations of structural, magnetic and electronic properties, Direct and indirect exchange interactions.
- Review of superconductivity, high temperature superconductors, Josephson junctions, flux dynamics, recent advances in superconductivity (MgB2, Fe-based superconductors, Borocarbide superconductor etc.)
- Dilute magnetic semiconductors, spin electronics and technology based on it.
- Ferroelectric, Multiferroic and Magnetoelectric materials.
- Colossal magnetoresistive manganites, Giant magnetoresistance, Ferrites, magnetic multilayers, Chare-orbital ordering, Phase-separation, Photofunctionality of some materials.
- Shape memory alloys: NiTi and magnetic alloys
- Recent/important discoveries in materials.

Suggested Books:

1. M. Getzlaff, Fundamentals of magnetism, Springer, 2010.
2. N. A. Spaldin, Magnetic Materials: Fundamentals and Device applications (2nd edition), Cambridge University Press, 2011.
3. Chaikin and Lubensky, Principles of condensed matter physics, Cambridge University Press, 2000.
4. B. D. Cullity, C. D. Graham, Introduction to magnetic materials, IEEE press and Wiley publications, 2009.
5. H. Ibach and H. Lutz, Solid State Physics: An introduction to materials science, Springer, 2002.
6. Ashcroft and Mermin, Solid State Physics, Wiley Publications.
7. J. Singleton, Band Theory and Electronic Properties of solids, Oxford University Press, 2001.
8. R. C. O'Handley, Modern Magnetic Materials: Principles and Applications, Wiley-Interscience

Publications, 2000.
9. R. E. Newnham, Properties of Materials: Anisotropy, Symmetry, Structure, Oxford University Press, 2005.
10. D. C. Lagoudas, Shape Memory Alloys: Modeling and Engineering Applications, Springer, 2008.
11. V. A. Chernenko, Advances in Shape Memory Materials: Magnetic Shape Memory Alloys, Trans Tech Publications, 2008.

Semester : III		
Course Name: Research project-I		**Course Code:** NTRP-611
Course type : Research project		**8 Hrs/ Week**
Total contact hours : 120 Hrs	**Theory Credit:** 4	**Marks** : 100

Learning outcomes:
On completion of this course, the students will be able:

References Books		
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Semester-IV

Course Type	Course Code	Course Name	Teaching Scheme (Hrs./ week)		Credits Assigned		
			Theory	Practical	Theory	Practical	Total Credits
Major Mandatory DSC	NTTC-650	Electrochemical Energy Conversion	2	-	2	-	8T
	NTTC -651	Corrosion Science and Engineering	2	-	2	-	
	NTTC -652	Nanophotonics and Plasmonics	2	-	2	-	
	NTTC -653	Spintronics and Magnetic Nanomaterials	2	-	2		
	NTLC-654	Laboratory –X	-	4	-	2	6L
	NTLC-655	Laboratory –XI	-	4	-	2	
	NTLC-656	Laboratory –XII	-	4	-	2	
DSE* (Choose anytwo)	NTTE-657	Non-Conventional Energy Sources	2	-	2	-	4T
	NTTE -658	Nanotechnology for Environmental Remediation	2	-	2	-	
	NTTE -659	Biosensors and Bioelectronics	2	-	2	-	
	NTTE -660	Applied Photoelectrochemistry	2	-	2	-	
Course Type: Research Project	NTRP-661	Research Project-II		8	-	4	4L
Total			**12**	**20**	**12**	**10**	**22**

*- a) Choice of DSE courses for offline mode is to the students subject to prior reporting of minimum ten students. b) Among the Four courses from DSE, one DSE is compulsory for offline mode and one among the remaining three for online (MOOC, NPTEL) mode. c) If online course for DSE is not available, students should choose two courses for offline mode.

Course Code Nomenclature:

DSC-Discipline Specific Core, **DSE**- Discipline Specific Elective, **T**-Theory, **L**- Laboratory course, **NTTC**- Nanotechnology Theory Core, **NTLC**-Nanotechnology Laboratory Core, **NTTE**-Nanotechnology Theory Elective, **NTRM**- Nanotechnology Research Methodology, **NTOJT**-Nanotechnology on the Job Training, **NTFP-** Nanotechnology Field Project

Semester: IV

	Semester: IV	
Course Name: Electrochemical Energy Conversion		**Course Code: NTTC-650**
Course type: DSC		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

This course provides a comprehensive understanding of electrochemical energy conversion technologies, emphasizing their role in sustainable energy solutions. Students will explore fundamental electrochemical principles, various types of electrochemical cells, and advanced materials used in these systems. Through case studies and real-world applications, the course aims to equip students with the knowledge to design and optimize electrochemical systems for energy conversion and storage.

Prerequisites:

- Basic knowledge of electrochemistry
- Understanding of thermodynamics and kinetics
- Prior coursework in materials science or physical chemistry

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Describe the importance and principles of electrochemical energy conversion.
- Understand the working principles and characteristics of different types of electrochemical cells, including fuel cells, electrolyzers, and batteries.
- Identify and evaluate materials used for electrodes, electrolytes, membranes, and separators in electrochemical systems.
- Analyze advanced electrochemical technologies such as high-temperature fuel cells, advanced batteries, and supercapacitors.
- Apply knowledge to integrate renewable energy sources with electrochemical systems and assess their real-world applications through case studies.

Course Outline:

Introduction to Electrochemical Energy Conversion

Overview of energy conversion technologies, Importance of electrochemical energy conversion in sustainable energy, Fundamentals of Electrochemistry

Basic electrochemical principles

Electrochemical cells and their components, Thermodynamics and kinetics of electrochemical reactions, Electrochemical Cells for Energy Conversion

Types of electrochemical cells: Fuel cells, electrolyzers, and batteries

Working principles and characteristics of fuel cells, Hydrogen production via water electrolysis, Batteries: Types, working principles, and applications

Materials for Electrochemical Energy Conversion

Electrode materials: Catalysts and conductors, Electrolytes: Types and properties, Membranes and separators

Advanced Electrochemical Technologies

High-temperature fuel cells: SOFCs and MCFCs, Advanced battery technologies: Li-ion, Na-ion, and solid-state batteries, Supercapacitors and hybrid systems

Applications and Case Studies

Renewable energy integration with electrochemical systems, Case studies on electrochemical energy systems in real-world applications

Suggested Books:

1. A.J. Bard and L.R. Faulkner, "Electrochemical Methods: Fundamentals and Applications," Wiley, 2000, ISBN: 978-0-471-04372-0.
2. D. Linden and T.B. Reddy, "Handbook of Batteries," McGraw-Hill, 2002, ISBN: 978-0-07-135978-8.
3. M. Winter and R.J. Brodd, "What Are Batteries, Fuel Cells, and Supercapacitors?" Chemical Reviews, 2004, DOI: 10.1021/cr020730k.
4. J. Newman and K.E. Thomas-Alyea, "Electrochemical Systems," Wiley, 2004, ISBN: 978-0-471-47756-3.
5. P.T. Moseley and J. Garche, "Electrochemical Energy Storage for Renewable Sources and Grid Balancing," Elsevier, 2014, ISBN: 978-0-444-62616-5.

	Semester: IV	
Course Name: Corrosion Science and Engineering		Course Code: NTTC-651
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:
This course provides an in-depth understanding of the fundamental and practical aspects of corrosion. It covers various types of corrosion, electrochemical mechanisms, environmental factors, and methods for corrosion testing, monitoring, and control. The course also includes case studies to illustrate corrosion issues in different industries and their prevention.

Prerequisites:
- Basic knowledge of chemistry, particularly electrochemistry
- Understanding of materials science principles

Learning Outcomes (LO):
Upon successful completion of this course, students will be able to:
- Define and classify different types of corrosion and understand their significance.
- Explain the electrochemical aspects of corrosion, including electrode potentials and thermodynamics.
- Describe the mechanisms of anodic and cathodic reactions, passivation, and localized corrosion.
- Identify the factors influencing corrosion in various environments such as atmospheric, aqueous, soil, and high-temperature conditions.
- Utilize laboratory and field techniques for corrosion testing and monitoring.
- Apply methods for controlling corrosion, including material selection, protective coatings, cathodic protection, and corrosion inhibitors.
- Analyze case studies to understand corrosion problems in different industries and devise appropriate prevention strategies.

Course Outline:
Introduction to Corrosion:
Definition and significance of corrosion, Types of corrosion: uniform, galvanic, crevice, pitting, intergranular, selective leaching, erosion, stress corrosion cracking.

Electrochemical Aspects of Corrosion:
Basic electrochemistry, Electrochemical cells, electrode potentials, and thermodynamics of corrosion, Pourbaix diagrams and their applications.

Corrosion Mechanisms:
Anodic and cathodic reactions, Mixed potential theory, Passivity and passivation, Localized corrosion mechanisms: pitting, crevice corrosion, and stress corrosion cracking.

Corrosion Environments:
Atmospheric corrosion, Aqueous corrosion, Soil corrosion, High-temperature corrosion.

Corrosion Testing and Monitoring:
Laboratory and field techniques, Electrochemical methods: potentiodynamic polarization, electrochemical impedance spectroscopy, Non-destructive testing (NDT) methods.

Corrosion Control Methods:

Material selection and design considerations, Protective coatings and linings, Cathodic protection: sacrificial anodes and impressed current systems, Corrosion inhibitors.

Case Studies in Corrosion:
Corrosion in various industries: oil and gas, marine, chemical processing, infrastructure, Failure analysis and prevention.

Suggested Books:

1. S. Khanna, Introduction to High Temperature Corrosion, ASM Publication, 2002, ISBN: 978-0871707628.
2. Evans, R. Ulick, An Introduction to Metallic Corrosion, Edward Arnold, London, UK, 1948, ISBN: 9780713120530.
3. Fontana, G. Mars, Greene and D. Norbert, Corrosion Engineering, McGraw-Hill, New York, 1967, ISBN: 0070214611.
4. Stephen, Cramer, S. Bernard and Jr. Covino, ASM Corrosion Fundamentals and Testing, ASM International, Edited, ISBN: 0-87170-705-5.

	Semester: IV	
Course Name: Nanophotonics and Plasmonics		Course Code: NTTC-652
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course provides an introduction to the field of nanophotonics and plasmonics, covering the fundamental principles and cutting-edge applications. It explores the interaction of light with nanomaterials, the properties and fabrication of photonic crystals, and the phenomena of surface plasmonics. The course also delves into the design and functioning of nanophotonic devices, metamaterials, and plasmonic nanostructures, along with their applications in various technological fields.

Prerequisites:

- Basic knowledge of optics and electromagnetism
- Understanding of quantum mechanics and materials science

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Explain the basic concepts and historical development of nanophotonics and plasmonics.
- Describe the interaction of light with nanomaterials and the optical properties that arise at the nanoscale.
- Understand the structure, fabrication, and applications of photonic crystals.
- Comprehend the fundamentals of surface plasmon polaritons and their applications in sensing and imaging.
- Design and analyze nanophotonic devices such as LEDs, lasers, photodetectors, and solar cells.
- Explore the properties and applications of metamaterials, including negative index materials and superlenses.
- Grasp the basics of nonlinear optics and its applications in signal processing.
- Investigate the role of quantum optics in nanostructures and its implications for quantum computing and secure communication.
- Fabricate and characterize plasmonic nanostructures and understand their applications in optoelectronics.

Course Outline:

- **Introduction to Nanophotonics:**
  Basic concepts and history, Light-matter interaction at the nanoscale, Optical properties of nanomaterials
- **Photonic Crystals:**
  Structure and fabrication, Bandgap properties, Applications in waveguides and filters
- **Surface Plasmonics:**
  Fundamentals of surface plasmon polaritons, Plasmon resonance in nanoparticles, Applications in sensing and imaging
- **Nanophotonic Devices:**
  Light-emitting diodes and lasers, Photodetectors, Solar cells and energy harvesting
- **Metamaterials:**
  Negative index materials, Superlenses and cloaking devices, Fabrication techniques
- **Nonlinear Nanophotonics:**
  Basics of nonlinear optics, Frequency conversion processes, Applications in signal processing
- **Quantum Optics in Nanostructures:**
  Quantum dots and single-photon sources, Quantum entanglement and computing,

Applications in secure communication

- **Plasmonic Nanostructures:**
  Fabrication and characterization, Plasmonic waveguides and circuits, Applications in optoelectronics

Suggested Books:

1. L. Novotny and B. Hecht, Principles of Nano-Optics, Cambridge University Press, 2012, ISBN: 9781107005464.
2. M. L. Brongersma and P. G. Kik, Surface Plasmon Nanophotonics, Springer, 2007, ISBN: 9781402052295.
3. S. A. Maier, Plasmonics: Fundamentals and Applications, Springer, 2007, ISBN: 9780387331508.
4. V. M. Shalaev and S. Kawata, Nanophotonics with Surface Plasmons, Elsevier, 2007, ISBN: 9780444528591.
5. P. N. Prasad, Introduction to Nanophotonics, John Wiley & Sons, 2013, ISBN: 9780470927136.

	Semester: IV	
Course Name: Spintronics and Magnetic Nanomaterials		Course Code: NTTC-653
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course offers an in-depth study of the field of spintronics and magnetic nanomaterials, focusing on the fundamental principles, synthesis, characterization techniques, and applications. It covers spin-dependent phenomena, various types of magnetic nanomaterials, and their synthesis methods. The course also explores the advanced characterization techniques used to analyze magnetic properties and the diverse applications of spintronics and magnetic nanomaterials in technology, medicine, and energy.

Prerequisites:

- Basic knowledge of quantum mechanics and solid-state physics
- Familiarity with materials science and nanotechnology concepts

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Understand the fundamentals of spintronics and spin-dependent phenomena.
- Describe various types of magnetic nanomaterials and their unique properties.
- Explain the different synthesis methods for creating magnetic nanomaterials.
- Utilize advanced characterization techniques to analyze magnetic properties.
- Discuss the applications of spintronics in devices such as magnetic tunnel junctions and spintronic sensors.
- Explore the applications of magnetic nanomaterials in data storage, biomedicine, environmental remediation, and energy systems.

Course Outline:

Introduction to Spintronics

Fundamentals of spintronics, Spin-dependent phenomena, Spin injection and detection, Spin relaxation and decoherence

Magnetic Nanomaterials

Types of magnetic nanomaterials, Magnetic nanoparticles, Magnetic thin films and multilayers, Magnetic nanocomposites

Synthesis of Magnetic Nanomaterials

Chemical synthesis methods, Physical vapor deposition (PVD), Molecular beam epitaxy (MBE), Sol-gel methods

Characterization Techniques

Electron microscopy (TEM, SEM), X-ray diffraction (XRD), Magnetometry (VSM, SQUID), Ferromagnetic resonance (FMR)

Applications of Spintronics

Magnetic tunnel junctions (MTJs), Spin-transfer torque devices, Spintronic sensors, Quantum computing

Applications of Magnetic Nanomaterials

Data storage, Biomedical applications (MRI, drug delivery), Environmental applications (wastewater treatment), Energy applications (batteries, supercapacitors)

Suggested Books:

1. **S. A. Wolf and D. D. Awschalom**, *Spintronics: A New Paradigm for Electronics*, Springer, 2006.

2. **D. J. Sellmyer and R. Skomski**, *Advanced Magnetic Nanostructures*, Springer, 2006.
3. **S. Blundell**, *Magnetism in Condensed Matter*, Oxford University Press, 2001.
4. **C. Kittel**, *Introduction to Solid State Physics*, 8th Edition, Wiley, 2005.
5. **T. Dietl**, *Functional Magnetic Nanostructures*, Wiley-VCH, 2010.

	Semester: IV	
Course Name: Laboratory Course X , XI and XII		Course Code: NTLC-654,655,656
Course type: DSC		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

The laboratory course provide hands-on experience and practical knowledge in the fields of electrochemical energy conversion, corrosion science and engineering, and nanophotonics and plasmonics. Students will engage in experiments that reinforce theoretical concepts, develop experimental skills, and foster a deeper understanding of advanced scientific principles. These courses emphasize the application of advanced techniques in material characterization, synthesis, and analysis, preparing students for research and industrial applications.

Prerequisites:

- Fundamental knowledge of physics, chemistry, and materials science.
- Prior coursework in nanotechnology, electrochemistry, and solid-state physics.

Learning Outcomes (LO):

Upon successful completion of these laboratory courses, students will be able to:

- Conduct experiments to understand the principles of electrochemical energy conversion and evaluate the performance of fuel cells, electrolyzers, and batteries.
- Analyze various types of corrosion and apply techniques to prevent and control corrosion in different environments.
- Utilize advanced characterization techniques to investigate the properties of magnetic nanomaterials and nanophotonic devices.
- Synthesize and evaluate the properties of magnetic nanomaterials and nanophotonic structures.
- Develop practical skills in using advanced instrumentation and analytical methods in nanotechnology and materials science.

Course Outline:

NTLC-654:

1. Cyclic voltammetry for studying redox reactions.
2. Hydrogen production via water electrolysis.
3. Potentiodynamic polarization to study corrosion rates.
4. Electrochemical impedance spectroscopy (EIS) for corrosion testing.
5. Galvanic corrosion testing of different metal pairs

NTLC-655:

1. Fabrication and optical characterization of photonic crystals
2. Surface plasmon resonance (SPR) sensing with metal nanoparticles.
3. Measurement of photoluminescence in quantum dots.
4. Characterization of metamaterials using transmission spectra.
5. Electrochemical impedance spectroscopy (EIS) of a supercapacitor

NTLC-656:

1. Testing and analysis of different electrolytes in a supercapacitor setup
2. Electrochemical synthesis of nanostructured electrode materials
3. Study of oxygen evolution reaction (OER) in electrolysis
4. Study of Hydrogen evolution reaction (HER) in electrolysis
5. Investigation of electrode materials for supercapacitors.

	Semester: IV	
Course Name: Non-Conventional Energy Sources		Course Code: NTTE-657
Course type: DSE		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:
This course provides an in-depth exploration of non-conventional energy sources, focusing on the principles, technologies, and applications of renewable energy systems. Topics include solar energy, wind energy, biomass, hydro-energy, ocean energy, geothermal energy, and hydrogen energy. Emphasis is placed on understanding the science and engineering behind these energy sources, their environmental impact, and their role in sustainable development.

Prerequisites:
- Basic knowledge of physics and chemistry.
- Prior coursework in energy systems or environmental science is beneficial.

Learning Outcomes (LO):
Upon successful completion of this course, students will be able to:
- Understand the fundamental principles and technologies of various non-conventional energy sources.
- Analyze and evaluate the performance of solar thermal and photovoltaic systems.
- Assess the potential and applications of wind energy in different environmental conditions.
- Describe the biochemical, chemical, and thermal conversion processes of biomass for energy production.
- Understand the principles and components of micro, mini, and small hydro systems, as well as ocean energy systems.
- Explain the origin, types, and applications of geothermal energy.
- Understand the production, storage, and utilization of hydrogen energy and the principles of fuel cells.

Course Outline:

Non-Conventional Energy Sources
Introduction: Energy resources; conventional and non-conventional, Energy and infrastructural development; Ecosystems, the environment and its cycles, energy and environment relationship
Solar energy: Solar radiation, radiation measurement and predictions; solar thermal conversions, basics, flat plate collectors-liquid and air type, theory of flat plate collectors, selective coating, advances collectors,; concentrators; Solar water heater, solar dryer; Solar phtovoltaic, science and technology of photovoltaic devices. organic PV cells.

Wind Energy: Metrology of wind speed distribution, energy estimation of wind regimes; Wing energy conversion, power torque and speed characteristics, wind turbine; Application of wind energy

Biomass: Biomass sources, CO_2 fixation potential of biomass, physicochemical characterstics of biomass as fuel; Biomass conversion, biochemical, chemical and thermal; biogas production mechanism, technology, types of digesters, plant design, biogas plant manure-utilization and manure values; Biomass gasification and combustion; anaerobic digestion of biomass; biomass utilization to produce solis, liquid and gaseous fuels

Hydro-energy: Overview of micro, mini and small hydro system; hydrology; elemnets of turbine; assessment of hydropower; selection and design criteria of turbines; speed and voltage regulations; Ocean energy; principle of ocean thermal energy conversion system, principles of ocean wave energy and tidal energy conversion

Geothermal energy: Origin of geothermal resources, types of geothermal deposits;
Hydrogen energy; Hydrogen production and storage; Fuel cells, principles of working, basic thermodynamics

Suggested Books:

1. Donald K., **Biomass for renewable energy, Fuels and chemicals**, Academic press
2. S.P. Sukhatme: **Solar energy principles of thermal collection and storage**, 2nd edition, Tata McGraw Hill
3. G. Boyle, **Renewable energy: Power for sustainable future**, Oxforfd OUP
4. J. Twidell and T. Weir, **Renewable Energy Resources**.
5. T. B. Johansson, H. Kelly, A.K.N. Reddy, R. H. William, **Renewable Energy- Sources for fuels and Electricity**.

	Semester: IV	
Course Name: Nanotechnology for Environmental Remediation		Course Code: NTTE-658
Course type: DSE		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course explores the role of nanotechnology in addressing environmental challenges, focusing on the use of nanomaterials for water treatment, air pollution control, soil remediation, and waste management. Students will gain an understanding of the synthesis, characterization, and application of nanomaterials in environmental remediation, as well as the regulatory and ethical considerations associated with their use.

Prerequisites:

- Basic understanding of chemistry and environmental science.
- Prior coursework in nanotechnology or materials science is beneficial.

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Understand the fundamental principles of nanotechnology and its significance in environmental remediation.
- Identify and describe various types of nanomaterials and their key properties for environmental applications.
- Synthesize and characterize nanomaterials using different methods and techniques.
- Apply nanotechnology-based solutions for water treatment, including the removal of contaminants and pathogens.
- Utilize nanomaterials for air pollution control and analyze their effectiveness in degrading airborne pollutants.
- Implement nanotechnology techniques for soil remediation and waste management.
- Assess the environmental and health risks associated with the use of nanomaterials.
- Understand the regulatory and ethical frameworks related to the deployment of nanotechnologies in environmental applications.

Course Outline:

Introduction to Nanotechnology and Environmental Remediation

Overview of nanotechnology and its significance in environmental science, Types of nanomaterials: nanoparticles, nanotubes, nanofibers, and nanocomposites, Key properties of nanomaterials that make them suitable for environmental applications.

Synthesis and Characterization of Nanomaterials

Methods of synthesizing nanomaterials: chemical vapor deposition, sol-gel process, hydrothermal synthesis, etc., Techniques for characterizing nanomaterials: X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and dynamic light scattering (DLS).

Nanotechnology for Water Treatment

Nanomaterials for removing contaminants from water: heavy metals, organic pollutants, pathogens., Mechanisms of adsorption, photocatalysis, and filtration, Case studies of nanotechnology-based water treatment systems.

Nanotechnology for Air Pollution Control

Application of nanomaterials in capturing and degrading airborne pollutants, Use of nanocatalysts for air purification, Case studies on nanotechnology solutions for industrial air emissions.

Soil Remediation and Waste Management
Techniques for soil remediation using nanomaterials: immobilization, degradation, and phytoremediation, Role of nanotechnology in waste management: recycling, treatment of hazardous waste, and energy recovery, Environmental and health risks associated with the use of nanomaterials.

Regulatory and Ethical Aspects
Regulatory frameworks for the use of nanotechnology in environmental applications, Ethical considerations in the deployment of nanotechnologies, Sustainable development and the role of nanotechnology.

Suggested Books:

1. Mark Wiesner and Jean-Yves Bottero, "Environmental Nanotechnology: Applications and Impacts of Nanomaterials," McGraw-Hill, 2007, ISBN: 978-0071477505.
2. Vicki H. Grassian, "Nanoscience and Nanotechnology: Environmental and Health Impacts," John Wiley & Sons, 2008, ISBN: 978-0470148051.
3. Mamadou Diallo, Jeremiah Duncan, Nora Savage, and Anita Street, "Nanotechnology for Environmental Remediation," Springer, 2013, ISBN: 978-3642382876.
4. Tharwat Tadros, "Nanotechnology for Water Treatment and Purification," Wiley-VCH, 2018, ISBN: 978-3527341956.
5. Jamie R. Lead and Emma Smith, "Environmental and Human Health Impacts of Nanotechnology," John Wiley & Sons, 2009, ISBN: 978-1405175446.

	Semester: IV	
Course Name: Biosensors and Bioelectronics		Course Code: NTTE-659
Course type: DSE		
Total contact hours: 30	Theory Credit: 2	Marks: 50

Course Description:

This course provides a comprehensive overview of biosensors and bioelectronics, focusing on the principles, design, fabrication, and applications of these devices. Students will learn about various types of biosensors, their transduction mechanisms, and the integration of biosensors with electronic circuits for practical applications in medical diagnostics, environmental monitoring, and other fields.

Prerequisites:

- Basic knowledge of electronics and instrumentation.
- Prior coursework in biochemistry or molecular biology is beneficial.

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Understand the fundamental principles and classifications of biosensors and bioelectronics.
- Explain the working principles of different types of biosensors including electrochemical, optical, piezoelectric, and thermal biosensors.
- Identify and describe the materials and fabrication techniques used in the development of biosensors.
- Integrate biosensors with electronic circuits for signal processing, conditioning, and data acquisition.
- Apply biosensors in various fields such as medical diagnostics, environmental monitoring, and industrial process control.
- Analyze real-world applications and case studies to understand the practical implementation and future trends of biosensors and bioelectronics.

Course Outline:

Introduction:

Overview of biosensors and bioelectronics, Classification and types of biosensors, Key concepts and terminologies

Transduction Principles:

Electrochemical biosensors, Optical biosensors, Piezoelectric biosensors, Thermal biosensors

Biosensor Fabrication and Design:

Materials used in biosensors, Fabrication techniques, Micro- and nano-fabrication for biosensors

Bioelectronics:

Integration of biosensors with electronic circuits, Signal processing and conditioning, Data acquisition and analysis

Applications of Biosensors and Bioelectronics:

Medical diagnostics, Environmental monitoring, Food and beverage industry, Industrial process control

Case Studies:

Analysis of real-world applications and case studies, Future trends and developments in biosensors and bioelectronics

Suggested Books:

1. Khandpur, R.S., "Handbook of Biomedical Instrumentation," McGraw-Hill Education, ISBN: 978-9339205430.
2. S.M. Sze, "Semiconductor Sensors," Wiley, ISBN: 978-0471546092.

	Semester: IV	
Course Name: Applied Photoelectrochemistry		**Course Code: NTTE-660**
Course type: DSE		
Total contact hours: 30	**Theory Credit: 2**	**Marks: 50**

Course Description:

This course explores the principles and applications of photoelectrochemistry, focusing on the interaction between light and electrochemical systems. It covers the fundamentals of electrochemical cells, the properties of semiconductor photoelectrodes, and the nanostructuring of these materials for enhanced photoelectrochemical performance. Special emphasis is placed on the photoelectrochemical splitting of water to produce hydrogen, a key process for renewable energy conversion.

Prerequisites:

- Basic knowledge of physical chemistry and solid-state physics.
- Prior coursework in materials science or nanotechnology is beneficial.

Learning Outcomes (LO):

Upon successful completion of this course, students will be able to:

- Understand the fundamental principles of electrochemistry and electrochemical cells.
- Explain the properties and behaviors of semiconductor photoelectrodes and their interfaces.
- Describe the effects of nanostructuring on the performance of semiconductor photoelectrodes.
- Analyze the processes and materials involved in photoelectrochemical water splitting.
- Evaluate the challenges and design strategies for improving photoelectrochemical systems for solar-driven hydrogen production.

Course Outline:

Introduction: Electrochemistry and Electrochemical Cells, Electrodes: Anode and Cathode, Equilibrium Potential of Electrode Reactions, Cathodic and Anodic Reactions, Electrode Reactions in Electron Transfer.

Semiconductor Photoelectrodes: Electron Energy Bands of Semiconductors, Chemical Potential and Electrochemical Potential, Graphical Representation of Energy Levels, Theory of Junction Formation, Metal-Schottky Junction, Semiconductor–Electrolyte Junction, Flow of Carriers Across the Junction, Depth of Charge Separation at the Interface of n- and p-Type Semiconductors, Nature of Potential at the Interface, Width of the Space Charge Region, and Quasi-Fermi Levels (QFLs). Semiconductor–Electrolyte Junction Under Illumination: Open Circuit Potential, Photovoltage and Photocurrent, Photocurrent Conversion Efficiency.

Nanostructured Semiconductor Photoelectrodes: Band Bending in Nanostructures, Effect of Surface Area, Determination of Quasi-Fermi Level Positions, Surface States and Fermi Level Pinning, Surface Recombination, Charge Separation and Collection, Charge Compensation and Charge Trapping.

Photoelectrochemical Water Splitting: Concept of Solar Driven Water Splitting and Production of Chemical Fuels/Hydrogen. Prospective Materials for Solar Driven Water Splitting and Associated Challenges. The Advanced Materials Design: Harvesting of Wider Solar Spectrum, Effective Separation and Transportation of Photo Charge Carriers, Earth Abundant Elements based Nanostructures.

Suggested Books:

1. Norio Sato, ***Electrochemistry at Metal and Semiconductor Electrodes***, Elsevier, The Netherlands, 2005, 0444828060
2. Yurii Pleskov, ***Semiconductor Photoelectrochemistry***, Springer, New York, USA, 2012, 9781468490800
3. Mary D Archer and Arthur J Nozik, ***Nanostructured and Photoelectrochemical Systems for Solar Photon Conversion***, World Scientific, London, 2008, 10 1860942555
4. R. Krol and M. Grätzel, ***Photoelectrochemical Hydrogen Production***, Springer, USA, 2011, 9781461413806

Semester : IV		
Course Name: Research project-II		**Course Code:** NTRP-661
Course type : Research project		**8 Hrs/ Week**
Total contact hours : 120 Hrs	**Theory Credit:** 4	**Marks** : 100

Learning outcomes:
On completion of this course, the students will be able:

References Books		
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