HINDUSTAN
INSTITUTE OF TECHNOLOGY & SCIENCE
(DEEMED TO BE UNIVERSITY)

M.Sc. Nanoscience and Technology

(Duration: 2 Years)

CURRICULUM and SYLLABUS

(Applicable for Students admitted from Academic Year 2023-24)

DEPARTMENT OF PHYSICS
SCHOOL OF LIBERAL ARTS AND APPLIED SCIENCES
HINDUSTAN INSTITUTE OF TECHNOLOGY AND SCIENCE

Motto:

To Make Every Man *a* Success *and* No Man *a* Failure

Vision:

To be an International Institute of Excellence, providing a conducive environment for education with a strong emphasis on innovation, quality, research and strategic partnership blended with values and commitment to society.

Mission:

- *To create an ecosystem that promotes learning and world class research.*
- *To nurture creativity and innovation.*
- *To instil highest ethical standards and values.*
- *To pursue activities for the development of the Society.*
- *To develop national and international collaborations with institutes and industries of eminence.*
- *To enable graduates to become future leaders and innovators.*

Value Statement:

Integrity, Innovation, Internationalization.

DEPARTMENT OF PHYSICS
(CENTRE FOR CLEAN ENERGY AND NANOCOVERGENCE)

Vision:

The Department of Physics strives to be at the Forefront of Nanoscience for the construction of a strong society through Science Education by being adaptive, innovative and constantly meeting the ever-growing demands of the scientific community in inter-disciplinary Nano Sciences and technologies, thus creating prepared minds to face the challenges.

Mission:

To educate the students to gain an understanding of the fundamentals of Nano Science and Technologies through a gradual exposure and equip them with practical skills to face the challenges in Technology Development

M. Sc. Nanoscience & Technology

PROGRAMME EDUCATIONAL OBJECTIVES (PEO'S)

The Programme Educational Objectives (PEOs) of MSc Nanoscience and Technology are:

PEO1: To produce masters who will have the ability to serve in the R&D domain on solving the problems in existing engineering aspects using the cutting edge technology tool called Nanotechnology and Technology.

PEO2: To gain thorough scientific knowledge of the fundamental structures of physical, biological, and chemical systems in terms of their molecular and atomic characteristics.

PEO3: Work productively as Nanotech professional by adopting to environment with lifelong learning and adhering to ethical standards and apply the knowledge acquired for the improvement of the society.

PROGRAMME'S OUTCOMES (PO's)

MSc Nanoscience and technology being an interdisciplinary subject offers knowledge, understanding and output that is integrated and Interdisciplinary in nature

PO1: Demonstrate: The MSc program uses research based knowledge and research methods including design of experiments, analysis, and consolidation of information and interpretation of data to demonstrate the outputs for rapid technological development in the field of energy, health, safety and sustainable environment.

PO2: Apply: Identify, formulate, analyse the complex scientific problems and amalgamate traditional research with advanced cutting-edge technologies to apply for product development and manufacturing.

PO3: Use: Create, select, adapt and apply appropriate techniques, resources to establish the abilities to carry out research/investigation and development work independently to solve practical problems.

PO4: Problem Solving:

Identify a timely opportunity and using innovation to pursue the prospects to create values and wealth for betterment of the individual and the society at large.

PO5: Recognise and Appreciate:

Recognize the need for multi-disciplinary technologies, exposure to modern tools, environmental sustainability and ability to attain lifelong learning in a broader contest while applying the contextual knowledge to access societal, health, safety and the consequent responsibilities relevant to the professional scientific practice in designing innovative Engineering routes leading to product development.

PROGRAMME'S SPECIFIC OUTCOMES (PSO's)

Understanding growing demand and the need to literate and motivate young generation towards the field of Nanoscience and technology. The field has already reduced the gap in between scientific research and technological breakthroughs in various area including medical, space, military, communication technology etc.

PSO1: Ability to synthesize, separate and characterize compounds using laboratory and instrumentation techniques required for a successful research scientist in the area of Nanoscience and technology.

PSO2: Ability to envisage, the current challenges in industrial development processes, work as a team and offer suitable solutions. Get Exposure to National & International research in the field of Nanotechnology and technology.

PSO3: A flair for working as a scientist in industry / academy for the development of new methods for a Sustainable environment.

PROGRAMME STRUCTURE

PSO1			PSO2		PSO3	
Ability to synthesize, separate and characterize compounds using laboratory and instrumentation techniques required for a successful research scientist in the area of Nanoscience and technology.			Ability to envisage the current challenges in industrial development processes, work as a team and offer suitable solutions. Get Exposure to National & International research in the field of Nanoscience and technology		A flair for working as a scientist in industry / academy for the development of new methods for a Sustainable environment.	
1	2	3	4	5	6	7
Courses - Knowledge based	**Courses related to Analysis**	**Courses on Synthesis**	**Courses - Skill based**	**Courses – Industrial Applicability**	**Interdisciplinary domain**	**Problem-Solving**
Introduction to Materials science	IOT based sensors	Insight into Fabrication and analysis of Nanomaterials	Project Seminar	Nanotechnology and its Applications	Introduction to Nano biotechnology	Project
Nanoscale magnetic material and devices	Modelling and simulation of nanomaterials	Composites and Smart materials	Project Seminar	Nanomaterial for Energy applications	Nanotechnology for health care	Project
Nanoelectronics and nano-photonics	Essentials of Research Process, Methodology and Ethics	MEMS and NEMS	Artificial Intelligence in Nanotechnology	Carbon based nanostructures and their applications	Internship	Project

SEMESTER- I									
SL. NO	**COURSE CATEGORY**	**COURSE CODE**	**NAME OF THE COURSE**	**L**	**T**	**P**	**C**	**S**	**TCH**
1	PC	ANO02001	Introduction to Materials Science	3	1	0	4	0	4
2	PC	ANO02002	Insight into Fabrication and analysis of Nanomaterials	3	0	2	4	1	5
3	PC	ANO02003	Modelling and Simulation of Nanomaterials	3	0	2	4	0	5
4	PC	ANO02004	Nanotechnology and its Applications	3	1	0	4	1	4
5	PC	ANO02005	Introduction to Nano Biotechnology	4	0	0	4	0	4
PRACTICAL									
6	PC	ANO02400	Synthesis and characterization of nanomaterials -I	0	0	4	2	0	4
			Total	16	2	8	22	2	**26**
L – Lecture; T – Tutorial; P – Practical; C – Credit; S- Self Study; TCH- Total Contact Hours									

SEMESTER- II

SL. NO	COURSE CATEGORY	COURSE CODE	NAME OF THE COURSE	L	T	P	C	S	TCH
1	PC	ANO02006	Essentials of Research Process, Methodology and Ethics	3	1	0	4	0	4
2	PC	ANO02007	Nanomaterials for Energy applications	3	0	2	4	1	5
3	PC	ANO02008	Composites and Smart materials	3	0	2	4	0	5
4	PC	ANO02009	Nanoelectronics and Nano-photonics	4	0	0	4	0	4
5	PC	ANO02010	Nanoscale magnetic materials and devices	3	1	0	4	0	4
PRACTICAL									
6	PC	ANO02401	Synthesis and characterization of nanomaterials -II	0	0	4	2	0	4
			Total	16	2	8	22	1	**26**
L – Lecture; T – Tutorial; P – Practical; C – Credit; S- Self Study; TCH- Total Contact Hours									

SEMESTER- III									
SL. NO	**COURSE CATEGORY**	**COURSE CODE**	**NAME OF THE COURSE**	**L**	**T**	**P**	**C**	**S**	**TCH**
1	PC	ANO02011	Carbon Based Nanostructures and their applications	3	0	2	4	0	5
2	PC	ANO02012	Micro and Nano fabrication	3	0	2	4	1	5
3	DE	*******	Department Elective -I	3	0	0	3	0	3
4	DE	*******	Department Elective -II	3	0	0	3	0	3
5	PC	ANO02800	Internship	0	0	0	4	0	0
6	PC	ANO02801	Project Phase-I	0	0	8	4	0	8
			Total	12	0	12	22	1	**24**
L – Lecture ; T – Tutorial ; P – Practical ; C – Credit; S- Self Study; TCH- Total Contact Hours									

SEMESTER- IV									
SL. NO	**COURSE CATEGORY**	**COURSE CODE**	**NAME OF THE COURSE**	**L**	**T**	**P**	**C**	**S**	**TCH**
1	PC	ANO02802	Project Phase-II	0	0	28	14	0	28
			Total	0	0	28	14	0	**28**
L – Lecture ; T – Tutorial ; P – Practical ; C – Credit; S- Self Study; TCH- Total Contact Hours									

TOTAL CREDITS: 80

LIST OF ELECTIVES

SEM	COURSE CATEGORY	COURSE CODE	NAME OF THE COURSE	L	T	P	C	S	TCH
III	DE	ANO02501	[1] Environmental Nanotechnology	3	0	0	3	0	3
III	DE	ANO02502	[1] IoT based sensors	3	0	0	3	0	3
III	DE	ANO02503	[2] MEMS and NEMS	3	0	0	3	0	3
III	DE	ANO02504	[2]Nanotechnology for health care	2	1	0	3	0	3
III	DE	ANO02505	[1]Artificial Intelligence in Nanotechnology	2	1	0	3	0	3
[1]: Academic research [2]: Industrial Applications									

SEMESTER - I

COURSE TITLE	INTRODUCTION TO MATERIALS SCIENCE	CREDITS	4

COURSE CODE	ANO02001	COURSE CATEGORY	PC	L-T-P-S	3-1-0-0
Version	1.0	Approval Details		LEARNING LEVEL	BTL-3

ASSESSMENT SCHEME

First Periodical Assessment	Second Periodical Assessment	Seminar/ Assignments/ Project	Surprise Test / Quiz	Attendance	ESE
15%	15%	10%	5%	5%	50%

Course Description	This course provides a comprehensive introduction, covering all major classes of materials. The characteristics of all main classes of materials, metals, polymers, and ceramics, are explained with reference to real-world examples. So, each module explained the properties with illustrative examples from the leading edge of the application.
Course Objective	1. To introduce and allow to explore the various crystal structures and types of bonds 2. To provide a strong knowledge of electronic properties of semiconductors and the origin of band theory. 3. To understand the concept of Gibb's phase diagram. 4. To impart knowledge on various properties of materials including magnetic properties. 5. To provide a strong knowledge of mechanical, optical, and thermal properties of Materials.
Course Outcome	Upon completion of this course, the students will be able to 1. Identify and understand crystal structures and types of bonds in materials 2. Appraise the electronic properties of semiconductors and the origin of band theory. 3. Illustrate the importance of the concept of Gibb's Phase diagram. 4. Describe the basic concept of magnetism of materials. 5. Identify and interpret the optical, mechanical and thermal properties of Materials.

Prerequisites: Knowledge of physics

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	1	1	-	2	1	1	1
CO-2	3	-	1	1	2	1	1	1
CO-3	3	2	1	1	2	1	1	1

CO-4	**3**	**2**	**1**	**-**	**1**	**1**	**1**	**1**
CO-5	**3**	**2**	**2**	**-**	**1**	**1**	**1**	**1**
1: Weakly related, 2: Moderately related and 3: Strongly related								

MODULE 1: Crystal structure	**(12)**
Crystal Structure and crystal defects, Structure of Matter- Amorphous, crystalline, crystals, polycrystals, symmetry, Unit Cells, Crystal Structures (Bravais Lattices), Crystallographic Directions, Crystallographic Planes, Miller Indices, Chemical Bonding- Atomic Bonding in solids, Types of bond: Metallic, Ionic, Covalent and Vander Waals bond; Hybridization; H-bonding. Crystal defects. **Suggested Readings:** Bravais lattices and seven crystal systems.	**CO-1 BTL-1 & 2**
MODULE 2: Electronic properties	**(12)**
Conducting and Semiconducting Materials Draw backs of classical theory – Fermi distribution function – Density of energy states, Origin of band gap in solids – Carrier concentration in an intrinsic semiconductor – electrical conductivity – band gap determination – Carrier concentration in n-type and p-types semiconductors – Hall effect – Determination of Hall coefficient. **Suggested Readings:** Determination charge carriers using Hall measurements	**CO-2 BTL-2 & 3**
MODULE 3: Phase diagram	**(12)**
Phase diagrams - Gibbs phase rule - Single component systems – Eutectic phase diagram – lever rule - Study of properties of phase diagrams - Phase transformation - Nucleation kinetics and growth **Suggested Readings**: Gibbs phase rule	**CO-2 BTL- 2 & 3**
MODULE 4: Magnetic properties	**(12)**
Magnetic Materials –Origin of magnetic moment – Bohr magneton – Weiss theory of Paramagnetism, ferromagnetism – Domain theory of ferromagnetism, Hysteresis – Ferrites – magnetic recording and readout – Storage of data – Tapes and floppy - magnetic disk drives. **Suggested Readings**: Types of magnetic materials	**CO-4 BTL-2**
MODULE 5: Optical & Mechanical Properties of materials	**(12)**
Thermal, Optical and Mechanical Properties of materials Heat capacity. Thermal expansion. Thermal conductivity. Optical Properties –Basic concepts. Optical properties of metals and non-metals. Application of optical phenomena. Mechanical Properties of Materials - Elastic deformation. Plastic deformation. Interpretation of tensile stress-strain curves, Yielding under multiaxial stress. **Suggested Readings**: Types of modulus and thermal properties	**CO-5 BTL-2 & 3**
TEXT BOOKS	

COURSE TITLE	INSIGHT INTO FABRICATION AND ANALYSIS OF NANOMATERIALS			CREDITS	4
COURSE CODE	ANO02002	COURSE CATEGORY	PC	L-T-P-S	3-0-2-1
Version	1.0	Approval Details		LEARNING LEVEL	BTL-3
ASSESSMENT SCHEME					
First Periodical Assessment	Second Periodical Assessment	Seminar/ Assignments/ Project	Surprise Test / Quiz	Attendance	ESE
15%	15%	10%	5%	5%	50%
Course Description	This course provides an in-depth study of the important instruments that have been developed to analyse nanostructured materials. Useful information that is derived from scattering processes involving X-rays, visible light, electrons, and neutrons will be studied. The study of spectroscopic techniques also forms part of the course. The application of these instruments to lithographic production techniques is also developed.				
Course Objective	1. To learn synthesis of nanoparticles using bottom-up approaches. 2. To understand the synthesis of nanoparticles using top-down approaches. 3. To impart knowledge on various deposition techniques for thin film preparation. 4. To analyse structural and thermal characterization techniques of nanomaterials. 5. To understand and compare various spectroscopy techniques.				

Course Outcome	Upon completion of this course, the students will be able to 1. Identify various bottom-up synthesis approaches 2. Explain the methods for nanomaterials synthesis using top-down approaches 3. Classify different thin film deposition techniques and its applications. 4. Compare and interpret structural and thermal characterization techniques 5. Analyse various optical characterization and spectroscopy techniques

Prerequisites: Basic knowledge in chemistry is required

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	-	2	2	2	2	1	1
CO-2	3	-	2	2	2	2	1	1
CO-3	3	-	2	2	2	2	1	1
CO-4	3	2	2	1	2	2	1	1
CO-5	3	2	2	1	2	2	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: SYNTHESIS: BOTTOM-UP APPROACH	**(12)**
Sol-gel synthesis - Spin coating – Solvothermal, hydrothermal, precipitation -Thin film techniques - Molecular beam epitaxy- Liquid phase epitaxy – Printing technologies - Sputtering technologies- Ion deposition -Ion implantation **Practical component:** Synthesis of nanoparticles using hydrothermal method **Suggested Readings:** 3D, 2D, 1D, and 0D materials and its properties	**CO-1 BTL-1 & 2**
MODULE 2: SYNTHESIS: TOP-DOWN APPROACH	**(12)**
Synthesis of bulk nanostructured materials – Lithographic techniques- Importance of lithographic technique- E-beam and ion beam Lithography-Principle and instrumentation-Etching Techniques-Wet chemical etching - Dry etching - Ball milling technique- Machining processes- mechanical alloying- micro milling **Practical component:** Synthesis of nanoparticles using ball milling method **Suggested Readings:** Various lithographic techniques	**CO-2 BTL-1 & 2**
MODULE 3: DEPOSITION TECHNIQUES	**(12)**
Electrodeposition- - Cathodic arc deposition - Pulsed laser deposition- Chemical Vapor Deposition (CVD) - Metal Organic Chemical Vapor Deposition (MOCVD) - Plasma CVD- Photo-enhanced CVD /Physical vapor deposition Combustion - Atomic Layer Deposition **Practical component:** Development of thin film using chemical vapour deposition method **Suggested Readings:** Thin film formation and nucleation	**CO-3 BTL-2 & 3**

MODULE 4: STRUCTURAL AND THERMAL CHARACTERIZATION OF MATERIALS	(12)
X- ray diffraction – Powder and crystal X-ray diffraction– Scanning electron microscopy- Transmission electron microscopy – Scanning Tunneling Microscopy (STM) - Principle and Instrumentation of Thermogravimetry (TGA) – Differential Thermal Analysis (DTA)and Differential scanning calorimetry (DSC) - Thermo mechanical analyzer (TMA) -Determination of thermo physical parameters. **Practical component:** Analysis of surface morphology using scanning electron microscopy **Suggested Readings:** Thermal properties	**CO-4 BTL-2 & 3**
MODULE 5: OPTICAL CHARACTERIZATION AND SPECTROSCOPY	**(12)**
UV-Vis spectroscopy – IR spectroscopy - Fluorescence spectroscopy - Photoluminescence – Cathodoluminescence - X ray Photoelectron Spectroscopy (XPS). Raman Spectroscopy – NMR Spectroscopy – ESR Spectroscopy - Atomic absorption spectroscopy (AAS) **Practical component:** Materials characterization using UV-Vis spectroscopy **Suggested Readings:** Spectroscopy techniques	**CO-5 BTL-2 & 3**

TEXT BOOKS	
1.	Horbart H. Willard, Instrumental Methods of Analysis, (2001). Wadsworth Publishing Co Inc; 7th edition ISBN-10: 0534081428
REFERENCE BOOKS	
1	W.Goddard, Handbook of Nano Science, engineering and technology, (2007), CRC Press: 2 nd edition, ISBN 9780429124761
2	Surender Kumar Sharma, Handbook of Materials (2018), Springer Cham: 1st edition, ISBN 978-3-319-92954-5
E-BOOKS	
1	Elton N. Kaufmann," Characterization of Materials" (2003), John Wiley Publication: 2 nd edition, ISBN: 978-1-118-11074-4
MOOC	
1	https://nptel.ac.in/courses/113105101

COURSE TITLE	MODELLING AND SIMULATION OF NANOMATERIALS			CREDITS	4
COURSE CODE	ANO02003	COURSE CATEGORY	PC	L-T-P-S	3-0-2-0
Version	1.0	Approval Details		LEARNING LEVEL	BTL-3

ASSESSMENT SCHEME					
First Periodical Assessment	**Second Periodical Assessment**	**Seminar/ Assignments/ Project**	**Surprise Test / Quiz**	**Attendance**	**ESE**
15%	**15%**	**10%**	**5%**	**5%**	**50%**

Course Description	This course will provide students with the fundamentals of computational problem-solving techniques that are used to understand and predict properties of nanoscale systems. Emphasis will be placed on how to use simulations effectively, intelligently, and cohesively to predict properties that occur at the nanoscale for real systems. The course is designed to present a broad overview of computational nanoscience and is therefore suitable for both experimental and theoretical researchers.
Course Objective	1. To introduce and allow to explore a wide range of simulations methods applicable for nanomaterials. 2. To design and predict nanoscale problems into "simulation-able" constituents. 3. To identify the importance of simulation as a guiding tool for the corresponding experiments 4. To identify and organize the computational tools for nano materials and nano devices 5. To understand the importance of Multiscale modelling for nanoscale systems
Course Outcome	Upon completion of this course, the students will be able to 1. Identify and understand the advantages and computational simulation for nanosystems 2. Define and identify the simulation methods applicable to various nanomaterials 3. Select appropriate computational methods that can help address specific materials, properties and processing 4. Organize and interpret the fundamentals and different concepts of computational simulation and analyze the outcomes. 5. Analyze and design simulation techniques for 1D and 2D materials.

Prerequisites: Previous knowledge of simulations is not required. The course is appropriate for advanced graduate students in materials science, engineering, chemistry, physics and biomedical fields.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**3**	**1**	**1**	**1**	**2**	**1**	**1**	**1**
CO-2	**3**	**2**	**2**	**2**	**1**	**2**	**1**	**1**
CO-3	**3**	**2**	**2**	**2**	**1**	**3**	**1**	**1**

CO-4	**3**	**2**	**1**	**2**	**1**	**3**	**1**	**1**
CO-5	**3**	**1**	**1**	**2**	**1**	**2**	**1**	**1**
1: Weakly related, 2: Moderately related and 3: Strongly related								

MODULE 1: INTRODUCTION TO COMPUTATIONAL SIMULATION OF NANO STRUCTURES	**(12)**
Introduction to quantum mechanics, Ab initio Simulations, Density functional theory (DFT) and approximations, Study of materials and nanostructures. Introduction to DFPT, Frist principle Phonon calculations and Vibrational Spectra, Introduction to Self-Consistent Field Method, Hellmann-Feynman stress tensor, Elastic Anisotropy, Concept of Simulation and Modelling. **Practical component:** Introduction to various modelling Tools like VESTA, CHEMCRAFT, CHEMSOL **Suggested Readings: Review of Modern Physics**	**CO-1 BTL-1 & 2**
MODULE 2: APPLICATIONS OF COMPUTATIONAL SIMULATION OF NANOMATERIAL	**(12)**
Computational Simulation of Nano materials in Energy Storage Applications. 2D Nano material for Lithium and other ion batteries (Sodium, Calcium), Diffusion mechanism, interface fracture, phase-boundary motion, Solid-Electrolyte-Interface (SEI) formation. Toxic Gas Sensing properties of 2D nanomaterials such as graphene, Transition Metal Di-chalcogenides (TMDs), MXenes etc. Various 2D modelling for high-capacity energy storage applications. Simulations of 2D and 1D for Biomedical Applications. **Practical component:** Introduction to DFT level Simulations of 2D nanomaterials **Suggested Readings:** Recently published Journals in the field of Nanomaterials	**CO-2 BTL- 2 & 3**
MODULE 3: COMPUTATIONAL SIMULATION AT AMBIENT CONDITIONS	**(12)**
Introduction to Molecular Dynamics (MD), Newton equations of motion, Verlet method, Pseudo-experiment – start, Equilibration and measurement, Boundary conditions, Errors of correlated time series, Mechanical quantities: temperature, internal energy, and pressure. Computer simulations of phase transitions. Modelling and MD simulation of Water solutes and Biomolecules. **Practical component**: Introduction to Molecular Dynamic Simulations **Suggested Readings**: Recently published Journals in the field of Nanomaterials	**CO-3 BTL-3**
MODULE 4: MECHANICAL MODELLING OF NANOMATERIALS	**(12)**

Many-body problem, Quantum mechanics of electrons and nuclei, Born-Oppenheimer approximation, Hartree and HF Theory. Concept of Crystal Structure, Introduction to Schrodinger's Equations, Introduction to 1st Principles calculation. Concept of DFT level simulations, Kohn-Sham (KS) Equation, Exchange correlation functional. Introduction to Pseudopotentials. Quantum Tunnelling and Quantum confinement effect in nanomaterials, Introduction to basis sets, Introduction to Nano systems. **Practical component**: Introduction to DFT level simulations **Suggested Readings**: Introduction to DFT	**CO-4 BTL-2**
MODULE 5: SIMULATION OF ONE & TWO -DIMENSIONAL NANOSTRUCTURES	**(12)**
Quantum confinement effect on 2D and 1D material, Overview of 2D and other 1D materials, and their Fundamental properties, Applications of 2D materials, Band structure, Dirac cone, mobility, and Fermi level. Tuning Electronic properties of 2D systems. Modelling of Functionalized Graphene and other 2D/1D structures. Simulation of 2D materials for Tuning Electronics and optoelectronics properties calculations. **Practical component:** Introduction to Simulation software like VASP, SIESTA **Suggested Readings**: Highly cited papers from Q1/Q2 based journals	**CO-5 BTL- 2 & 3**

TEXT BOOKS	
1	R. M. Martin, Electronic Structure: Basic Theory and Practical Methods, (2012), Cambridge University Press; 1st edition, ISBN-10 : 0521534402
REFERENCE BOOKS	
1	D. Sholl, J. A Steckel, Density Functional Theory: A Practical Introduction, 2009, Wiley-Interscience; 1st edition, ISBN-10 : 0470373172
2	Perla Balbuena, Jorge M. Seminario, Nanomaterials: Design and Simulation, 2006, ISBN: 9780444528261.
E BOOKS	
1	M. A. Garrison Darrin, J. L. Barth, Systems Engineering for Microscale and Nanoscale Technologies, (2017) ISBN-10 : 1138075728
MOOC	
1	https://nanohub.org/resources/23836

COURSE TITLE	**NANOTECHNOLOGY AND ITS APPLICATIONS**			**CREDITS**	**4**
COURSE CODE	**ANO02004**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-1-0-1**

Version	1.0	Approval Details		LEARNING LEVEL	BTL-2
ASSESSMENT SCHEME					
First Periodical Assessment (Theory + Practical)	**Seconds Periodical Assessment (Theory + Practical)**	**Weekly assignment/Observation / lab records as approved by DEC**	**Surprise Test / Quiz as approved by DEC**	**Attendance**	**ESE (Theory + Practical)**
15%	**15%**	**10%**	**5%**	**5%**	**50%**
Course Description	This course deals with diverse applications of nanotechnology. It covers the application in the electronic and electrical field. The course also covers the usage of nanomaterials in the biomedical and pharmaceutical industries. The emphasis of the applications of nanotechnology in the chemical industry. Nanotechnology in agriculture and food technology is provided.				
Course Objective	1. To understand the applications of nanomaterials in electronic devices. 2. To identify the applications of nanotechnology in the biomedical sector. 3. To explore nano-based technology in the chemical industry. 4. To summarize different applications of nanomaterials in agriculture sector 5. To demonstrate the various applications of nanomaterials in textile and cosmetic industry				
Course Outcome	Upon completion of this course, the students will be able to 1. Identify the types of nanomaterials in the electrical and electronic sector. 2. Summarize application of various nanomaterials in the pharmaceutical sector. 3. Identify and interpret the application of nanomaterials in the chemical industry. 4. Illustrate the role of various nanomaterials in the agriculture and food industries. 5. Explain the application of nanomaterials in the textile and cosmetic industries.				
Prerequisites: Basics of Chemistry and Physics.					

CO, PO AND PSO MAPPING

	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	-	2	1	1	-	1	2
CO-2	3	-	2	1	1	-	2	2
CO-3	3	-	2	1	1	-	2	2
CO-4	3	-	2	1	1	-	2	2

CO-5	**3**	**-**	**2**	**1**	**1**	**-**	**2**	**2**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: NANOTECHNOLOGY IN ELECTRICAL AND ELECTRONICS INDUSTRY	**(12)**
Advantages of nanomaterials in electrical and electronic devices –Electronic circuit chips – Lasers - Micro and Nano-Electromechanical systems – Sensors, Actuators, Optical switches, Bio-MEMS –Diodes and Nano-wire Transistors - Data memory –Lighting and Displays – Filters (IR blocking) – Quantum optical devices – Lead-free solder – Nanoparticle coatings for electrical products **Suggested readings:** Electronic devices	**CO-1** **BTL -1 & 2**
MODULE 2: NANOTECHNOLOGY IN BIOMEDICAL AND PHARMACEUTICAL INDUSTRY	**(12)**
Nanoparticles in bone substitutes and dentistry – Implants and Prosthesis - Reconstructive Intervention and Surgery – Nanorobotics in Surgery – Photodynamic Therapy - Nanosensors in Diagnosis– Neuro-electronic Interfaces – Protein Engineering – Drug delivery – Therapeutic applications **Suggested readings:** Diagnosis using nanosensors	**CO-2** **BTL-2**
MODULE 3: NANOTECHNOLOGY IN CHEMICAL INDUSTRY	**(12)**
Nanocatalyts – Smart materials – Heterogynous nanostructures and composites – Nanostructures for Molecular recognition (Quantum dots, Nanorods, Nanotubes) – Molecular Encapsulation and its applications – Nanoporous zeolites – Self-assembled Nanoreactors - Organic electroluminescent displays **Suggested readings:** Smart materials, LED	**CO-3** **BTL 2**
MODULE 4: NANOTECHNOLOGY IN AGRICULTURE AND FOOD TECHNOLOGY	**(12)**
Nanotechnology in Agriculture -Precision farming, Smart delivery system – Insecticides using nanotechnology – Potential of nano-fertilizers - Nanotechnology in Food industry - Packaging, Food processing - Food safety and bio-security – Contaminant detection – Smart packaging **Suggested readings:** Nanomaterials in agricultural field.	**CO-4** **BTL-1 & 2**
MODULE 5: NANOTECHNOLOGY IN TEXTILES AND COSMETICS	**(12)**
Engineering application – Polymer nanofibers - Swim-suits with shark-skin-effect, Soil repellence, Lotus effect - Nano coatings in textiles – Smart textiles. Cosmetics – Formulation of cosmetic products – Sun-screen dispersions for UV protection using Titanium oxide – Colour cosmetics **Suggested readings:** Polymers in nanofield.	**CO-5** **BTL-2**

TEXT BOOKS

1	Mark A. Ratner and Daniel Ratner,Nanotechnology: A Gentle Introduction to the Next Big Idea, (2002), Pearson; 1st edition, ISBN: 9780131014008

2	Bharat Bhushan, Springer Handbook of Nanotechnology, (2010), Springer; 3rd ed., ISBN:20103642025242.
REFERENCE BOOKS	
1	Lynn J. Frewer, Willehm Norde, R. H. Fischer and W. H. Kampers, Nanotechnology in the Agri-food sector, (2011),Wiley-VCH Verlag, 1st edition. ISBN:9783527330607
2	J. Brown and K. Stevens, Nanofibers and Nanotechnology in Textiles, (2007), Woodhead Publishing Limited, Cambridge,1st edition ,ISBN: 9781845691059
E BOOKS	
1	Nandita Dasgupta, Shivendu Ranjan, Eric Lichtfouse. Environmental Nanotechnology, , (2018), Springer publishing limited, ISBN: 978-3319760896
MOOC	
1	https://www.my-mooc.com/en/mooc/nanotechnology-and-nanosensors-part-2

COURSE TITLE	**INTRODUCTION TO NANOBIOTECHNOLOGY**			**CREDITS**	**4**
COURSE CODE	**ANO02005**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**4-0-0-0**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL-2**
ASSESSMENT SCHEME					
First Periodical Assessment (Theory + Practical)	**Seconds Periodical Assessment (Theory + Practical)**	**Weekly assignment/Observation / lab records as approved by DEC**	**Surprise Test / Quiz as approved by DEC**	**Attendance**	**ESE (Theory + Practical)**
15%	**15%**	**10%**	**5%**	**5%**	**50%**
Course Description	This course deals with the fundamentals of biocompatible materials. It covers the basic concept of Bio composites with illustrations. The course also covers the different methods adopted in bioengineering. Emphasis of the various types of interaction with implanted material.				
Course Objective	1. To create knowledge of biocompatible materials. 2. To appraise the principles of biocomposites and their applications. 3. To describe the applications of nanoparticles and polymers in bioengineering. 4. To illustrate different types of targeted drug delivery using nanoparticles. 5. To explain the various types of biological interactions with implanted materials				
Course Outcome	Upon completion of this course, the students will be able to 1. List the elemental principles of biocompatible materials				

	2.Describe the mode of action of biocomposites and its application 3.Summarize recent developments of nanomaterials in the field of bioengineering 4. Design and study the possibility of application of various nanoparticles in targeted drug delivery 5. Understand the advances of biological interactions with implanted materials

Prerequisites: Understanding concepts of Nanotechnology and biology

CO, PO AND PSO MAPPING

	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**3**	**-**	**-**	**1**	**-**	**-**	**1**	**1**
CO-2	**3**	**-**	**-**	**1**	**-**	**-**	**1**	**1**
CO-3	**3**	**-**	**-**	**1**	**-**	**-**	**1**	**1**
CO-4	**3**	**-**	**-**	**1**	**-**	**-**	**1**	**1**
CO-5	**3**	**-**	**-**	**1**	**-**	**-**	**1**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: BIOCOMPATIBLE MATERIALS	**(12)**
Bio-mineralised Inorganic Nanomaterials – Nanostructures and Dynamics of Biocompatible surfactant monolayers and bilayers – Bio-interface, Bio-conjugation, Bio-matrix based on bioinspired phospholipids polymers. **Suggested Readings:** Biocompatible materials	**CO-1 BTL -1 & 2**
MODULE 2: BIO COMPOSITES AND ITS APPLICATION	**(12)**
Self-assembly of ionic-complementary peptides and their applications in nano-biotechnology –from nanocluster assays to optical biochips–bioactive nanomaterials in bone grafting and tissue engineering- inorganic /polymer nano composites for dental restoration and bone replacement applications. Nanotechnology in organ printing, Bio inks for 3D bio-printing - Applications and future trends. **Suggested Readings:** Bio composites and its application	**CO-2 BTL-2**
MODULE 3: BIOENGINEERING	**(12)**
DNA based artificial nanostructures: fabrication, properties and applications – Nucleic acid engineered nanomaterials and their applications: Protein patterning for applications in biodevices. Polymers nanofibers and their applications in bioengineering – functional polymers for bone tissue engineering applications – applications of nanotechnology in tissue engineering **Suggested Readings:** Bioengineering	**CO-3 BTL 2**
MODULE 4: DRUG DELIVERY	**(12)**

Vesicles and liposomes in sensor technology –Self-assembling nanostructured injectable polymeric gels for drug delivery - Engineering surface erodable polyanhydrides with tailored microstructure for controlled drug and protein delivery **Suggested reading :** Drug delivery	**CO-4** **BTL-2**
MODULE 5 : INTERACTION WITH IMPLANTED MATERIAL	**(12)**
Advantages of Nanomaterials use as implants – biological response of implanted materials – desirable and undesirable reactions of the body with implanted materials. Protein interactions with implanted materials: - cellular recognition of Proteins Adsorbed on material surfaces – adhesion – migration differentiation – Cellular Extra cellular Matrix deposition leading to tissue regeneration – foreign-body response – inflammatory response **Suggested reading** : Implanted materials	**CO-5** **BTL-2**
TEXT BOOKS	
1	Jon J. Kellar (Ed) Functional fillers and nanoscale minerals; new markets/ new horizons, 2006, SME science, ISBN: 0873352475
REFERENCE BOOKS	
1	H.S. Nalwa (Ed) Handbook of Nanostructured Biomaterials and their applications in nanobiotechnology, 2005, American Scientific Publishers. ISBN: 1-58883-004-7
2	Ali Khademhosseini, Gulden Camci-Unal, 3D Bio-printing in Regenerative Engineering, Principles and Applications, 2018, 1st edition, CRC press. ISBN: 9781315280493
E BOOKS	
1	Young-Chul Lee, Ju-Young Moon, Introduction to Bionanotechnology (2020) Springer Singapore, 1 st edition, ISBN978-981-15-1293-3
MOOC	
1	https://doi.org/10.1021/acs.chemrev.7b00258

COURSE TITLE	**SYNTHESIS AND CHARACTERIZATION OF NANOMATERIALS -I**			**CREDITS**	**2**
COURSE CODE	**ANO02400**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**0-0-4-0**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL-4**

ASSESSMENT SCHEME					
Experimental	**Analysis**	**Result**	**Viva**	**Record**	**ESE**
20%	**10%**	**10%**	**10%**	**10%**	**40%**

Course Description	On successful completion of the course the students should have learnt about the synthesis of nanomaterials, quantum dot and conducting polymers. Characterization of the synthesized materials.
Course Objective	1. To synthesis semiconductor materials by sol-gel and hydrothermal method 2. To fabricate porous nanomaterial by different chemical methods 3. To extract bio-solvents from edible wastes and its characterizations 4. To analyze the semiconductor materials. 5. To determine structural and optical properties of nanomaterials
Course Outcome	Upon completion of this course, the students will be able to 1. Synthesize nanomaterials by wet synthesis routes 2. Synthesize porous nanomaterials. 3. Able to perform extraction of nanomaterials 4. Verify the morphology, particle size and elemental composition of nanomaterials. 5. Able to analyse the electronic and optical properties using characterization tools.

Prerequisites: Knowledge of chemistry in the undergraduate level.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	3	2	1	1	3	1	1
CO-2	3	3	2	1	1	3	1	1
CO-3	3	3	2	1	1	3	1	1
CO-4	3	3	2	1	1	3	1	1
CO-5	3	3	2	1	1	3	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: LIST OF EXPERIMENTS	**(45L)**
1. Synthesis of metal oxide nanoparticles by sol-gel method	CO-1 BTL-3
2. Synthesis of metal chalcogenides using hydrothermal method	CO-1 BTL-3
3. Synthesis of graphic carbon nitride by thermal decomposition method	CO-2 BTL-3
4. Fabrication of porous alumina or anodized alumina template.	CO-2 BTL-3

5. Extraction of Bio solvent from edible waste materials and analysed by UV-Visible measurements	CO-3 BTL-3
6. Green Synthesis of carbon quantum dot and its photoluminescence analysis	CO-3 BTL-4
7. Synthesis of graphene quantum dot and characterize them by SEM with EDAX	CO-4 BTL-4
8. Verification of Lambert Beer's law and determination of concentration of solution by UV-Vis spectrophotometer.	CO-4 BTL-4
9. Estimation of average grain/crystallite size, unit cell parameters, micro-strain by recording the X-ray diffraction pattern of the given sample.	CO-5 BTL-4
10. Determination of optical band gap of the given semiconducting materials by measuring UV-Visible transmission spectrum.	CO-5 BTL-4

TEXT BOOKS	
1.	Kalyanaraman Rajagopal, A Practical manual on synthesis of nanoparticles and its Applications in Biology, 2017, Digital Age Publishers
REFERENCE BOOKS	
1.	Ram K.Gupta, Conducting Polymers: Chemistries, Properties and Biomedical Applications, 2022, CRC Press, ISBN: 9781003205418
2.	Nintu Mandal, Agricultural Nanotechnology: Basics And Practicals, 2019, NIPA books, ISBN: 9387973859
E BOOKS	
1.	https://pubs.acs.org/doi/abs/10.1021/ed008p1009.2
MOOC	
1.	https://www.mooc-list.com/tags/chemistry

Semester - II

COURSE TITLE	**Essentials of Research Process, Methodology and Ethics**			**CREDITS**	**4**
COURSE CODE	**ANO02006**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-1-0-0**

Version	1.0	Approval Details		LEARNING LEVEL	BTL-3
ASSESSMENT SCHEME					
First Periodical Assessment	**Second Periodical Assessment**	**Seminar/ Assignments/ Project**	**Surprise Test / Quiz**	**Attendance**	**ESE**
15%	**15%**	**10%**	**5%**	**5%**	**50%**
Course Description	Research design in Material sciences and Nano sciences; Research Ethics; Research proposal development; Literature review; Problem and objective formation; Hypothesis statement and mathematical model development; Data collection; Research statistics and tools; Data analysis; Discussion, conclusion, recommendation, dissemination and application of research.				
Course Objective	1. Introduction of Conducting Scientific Research. 2. Identify Research Questions and Research Methodology 3. Understand and design the research problems 4. Compare and classify different data analysis methods 5. Understand research ethics				
Course Outcome	Upon completion of this course, the students will be able to 1. Understand the concept of academic Research Methodology and applications. 2. Demonstrate knowledge of research processes (reading, evaluating, and developing) 3. Perform literature reviews using print and online databases. 4. Identify, explain, compare, and prepare the key elements of a research proposals and reports 5. Compare, estimate and recognize quantitative and qualitative research and support research ethics				
Prerequisites: Basic in literature survey, Use Internet.					

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	-	2	1	1	2	-	-	-
CO-2	-	1	1	1	-	-	1	-
CO-3	-	3	1	1	-	1	-	-
CO-4	-	-	2	2	-	-	-	
CO-5	-	1	1	1	1	1	-	-

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: OBJECTIVES AND TYPES OF RESEARCH	(12)
Understanding the language of Research - Concept, Construct, Definition, Variable. Research Process. Motivation and objectives, Research methods vs Methodology. Types of research; Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical. **Suggested Readings:** Published Journals	**CO-1 BTL- 1 & 2**
MODULE 2: RESEARCH FORMULATION	**(12)**
Principles of data documentation, protocol development, research questions and hypothesis driven research, technical writing fundamentals. 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. Critical literature review; Identifying the gap areas from literature review, Development of working hypothesis **Suggested Readings:** Review papers from Scopus indexed journals	**CO-2 BTL- 1 &2**
MODULE 3: RESEARCH DESIGN AND METHODS	**(12)**
Concept and Importance in Research- Features of a good, research design- Exploratory Research Design- concept, Types and uses, Descriptive Research Designs - concept, types and uses. Types of research reports, Brief reports and Detailed reports; Report writing: Structure of the research report- Formulation rules for writing the report: Guidelines for presenting tabular data, Guidelines for visual Representations, Illustrations and tables - Bibliography, referencing and footnotes. **Suggested Readings:** Highly cited papers from Q1/Q2 based journals	**CO-3 BTL-2**
MODULE 4: DATA COLLECTION AND ANALYSIS	**(12)**
Execution of the research - Observation and Collection of data - Methods of data collection- Sampling Methods- Data 8 Processing and Analysis strategies - Data Analysis with Statistical Packages - Hypothesis-testing - Generalization and Interpretation. Different steps in the data 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. **Suggested Readings:** Recently published Journals in the related field	**CO-4 BTL-3**
MODULE 5: RESEARCH ETHICS	**(12)**

Plagiarism, regulatory principles, safety in research, ethics in stem cell research, ethics in clinical research, ethics in nanomaterials based research. Environmental impacts, Ethical issues, Commercialization, Copy-right, royalty - Intellectual property rights and patent law, Trade Related aspects of Intellectual Property Rights, Reproduction of published material, Plagiarism, Citation and acknowledgement, Reproducibility and accountability. **Suggested Readings:** plagiarism	**CO-5** **BTL-2**

TEXT BOOKS	
1	Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., An introduction to Research Methodology, 2002, RBSA Publishers, ISBN: 8176111651
REFERENCE BOOKS	
1	Bryman, A. & Bell, E. (2003) Business research methods. New York, 2003, Oxford University Press. ISBN: 9780198869443
2	Kothari, C.R., Research Methodology: Methods and Techniques. 1990.New Age International. 418p.
3	Leedy, P. D. Practical Research: Planning and design. Washington: (1980). Mc Millan Publishing Co., Inc
E BOOKS	
1	http://www.pitt.edu/~super7/43011-44001/43911.ppt
MOOC	
1	https://www.mooc-list.com/tags/research-methodology

COURSE TITLE	**NANOMATERIALS FOR ENERGY APPLICATIONS**			**CREDITS**	**4**
COURSE CODE	**ANO02007**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-0-2-1**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Second Periodical Assessment**	**Seminar/ Assignments/ Project**	**Surprise Test / Quiz**	**Attendance**	**ESE**
15%	**15%**	**10%**	**5%**	**5%**	**50%**
Course Description	This course is designed to understand the basic concepts of electrochemical energy storage systems and conversion technology. The curriculum covers basic concepts of energy storage systems and conversion technology. This course				

	covers different types of fuel cell, battery, supercapacitor and solar cells and also includes uses and challenges of nanomaterials in energy storage and conversion technology.
Course Objective	1. To describe the concept of Electrochemistry 2. To learn the developments and future trends of nanomaterials in Fuel cells 3. To identify different types of photovoltic cells 4. To understand the importance of nanomaterials in rechargeable batteries 5. To classify different kind of supercapacitors
Course Outcome	Upon completion of this course, the students will be able to 1. Explain basic concepts of Electrochemistry 2. Illustrate the working principle of fuel cells 3. Explore the basic concepts of photovoltic cells and future trends 4. Assess the role of nanomaterials in rechargeable batteries 5. Compare carbon based supercapacitors and pseudo capacitors

Prerequisites: Basics of Electrochemical energy storage and conversion devices

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	1	1	1	1	1	1	1	1
CO-2	2	2	2	1	2	1	1	3
CO-3	2	1	2	1	2	2	2	3
CO-4	2	1	3	1	3	1	1	3
CO-5	2	1	3	1	3	1	1	3

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: FUNDAMENTAL CONCEPTS IN ELECTROCHEMISTRY	**(12)**
Electrochemical Cell, Faraday's laws, Electrode Potentials, Thermodynamics of electrochemical cells, Polarization losses in electrochemical cells, Electrode process and kinetics, Electrical double layer, Photoelectrochemical cell, thermoelectric effect. **Practical component:** Electrode Process – Faradic and Non faradic process **Suggested Readings:** Thermodynamics of electrochemical cells and electrical double layer	**CO-1 BTL-1 & 2**

MODULE 2: ENERGY CONVERSION SYSTEMS	**(12)**
Issues and Challenges of functional Nanostructured Materials for electrochemical Energy, Conversion Systems, Fuel Cells, Principles and nanomaterials design for; Proton exchange membrane fuel cells (PEMFC); Direct methanol fuel cells (DMFC); Solid-oxide fuel cells (SOFC), Current status and future trends **Practical component:** Fabrication of electrocatalyst for fuel cell	**CO-2 BTL- 2 & 3**

Suggested Readings: Different types of Fuel cell	
MODULE 3: PHOTOVOLTAIC SYSTEMS	**(12)**
Principles of photovoltaic energy conversion (PV), Types of photovoltaic Cells, Physics of photovoltaic cells, Organic photovoltaic cell cells, thin-film Dye-Sensitized Solar Cells, Quantum dot (QD) Sensitized Solar Cells (QD-SSC), Organic-Inorganic Hybrid Bulk Heterojunction (BHJ-SC) Solar cells, Current status and future trends. **Practical component:** Bandgap calculation of semiconductor material **Suggested Readings:** Physics of Photovoltaic cells	**CO-3 BTL- 1 & 2**
MODULE 4: RECHARGEABLE BATTERIES	**(12)**
Issues and Challenges of functional Nanostructured Materials for battery technology, Primary and Secondary Batteries (Lithium-ion Batteries), Different types of batteries Li-S, Li-Polymer, Li-O, Metal ion batteries, Cathode and anode materials, Nanostructured Carbon-based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends. **Practical component:** Capacity measurements of Lithium ion battery **Suggested Readings:** Issues and Challenges of functional Nanostructured Materials for battery technology	**CO-4 BTL-2 & 3**
MODULE 5: ELECTROCHEMICAL CAPACITORS	**(12)**
Capacitor, Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Hybrid supercapacitor, Nanostructured Carbon-based materials, Redox capacitor Nano oxides, Conducting polymer based materials, Current status and future trends. **Practical component:** Specific capacitance calculation from CV **Suggested Readings:** Electrochemical supercapacitors and pseudo capacitors	**CO-5 BTL-2 & 3**

TEXT BOOKS	
1	Allen J.Bard and Larry R Electrochemical methods: Fundamentals and Applications, (2004). John Wiley & Sons. Inc, 2nd Edition ISBN: 978-0-471-04372-0
REFERENCE BOOKS	
1	D. Linden. Thomas B. Reddy, Handbook of Batteries, 3rd Edition, (2002) McGraw-Hill, New York, ISBN: 0071359788
2	P Wurfel, Physics of Solar Cells: From Basic Principles to Advanced Concepts (2009) Wiley-VCH Verlag GmbH; 1st edition ISBN -10: 3527408576
E BOOKS	
1	http://www.freebookcentre.net/chemistry-books-download/Electrochemical-Energy-Systems.html

MOOC	
1	https://www.mooc-list.com/tags/solar-pv

COURSE TITLE	COMPOSITES AND SMART MATERIALS			CREDITS	4
COURSE CODE	ANO02008	COURSE CATEGORY	PC	L-T-P-S	3-1-0-0
Version	1.0	Approval Details		LEARNING LEVEL	BTL-3

ASSESSMENT SCHEME

First Periodical Assessment	Second Periodical Assessment	Seminar/ Assignments/ Project	Surprise Test / Quiz	Attendance	ESE
15%	15%	10%	5%	5%	50%

Course Description	This course introduces composites and smart materials and its application in Nanotechnology to develop functional materials and devices. It covers various types of composites and the production methods. It discusses about smart materials and its industrial applications.
Course Objective	1. To understand the fundamental concept of composites and its classifications 2. To learn the synthesis techniques of nanocomposite material 3. To gain knowledge about the mechanics of nanocomposite 4. To learn the different types of smart materials 5. To impart knowledge about the applications of smart materials
Course Outcome	Upon completion of this course, the students will be able to 1. Learn the fundamental concept and importance of composites 2. Gain knowledge about the production techniques for nanocomposite materials 3. Understand the mechanics of composite material. 4. Classify and understand mechanics of smart materials 5. Understand the different important applications of smart materials.

Prerequisites: Basic knowledge in composites and smart materials

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	2	1	1	1	1	2	1	1
CO-2	2	1	2	1	2	2	2	1
CO-3	2	1	2	1	2	1	1	1
CO-4	1	1	2	1	2	1	1	1
CO-5	1	1	2	1	2	1	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related	
MODULE 1: TYPES OF COMPOSITES	**(12)**
Introduction and overview of composite materials and their need, Enhancement of properties, classification of composites, Matrix-Polymer matrix composites (PMC), Metal matrix composites (MMC), Ceramic matrix composites (CMC), Application of composites. Reinforcements and matrices, Types of reinforcements, Types of matrices, Types of composites, Carbon Fibre composites, Properties of composites in comparison with standard materials, Application of composites. **Practical component:** Fabrication of Polymer matrix composites **Suggested Readings:** Composites and types	**CO-1** **BTL-2**
MODULE 2: PRODUCTION TECHNIQUES OF COMPOSITES	**(12)**
Processing of cast composites - XD process, Spray processes (Osprey Process, Rapid solidification processing), In-situ Dispersion Processes (Stir-casting & Compo casting, Screw extrusion), Liquidmetal impregnation technique (Squeeze casting, Pressure infiltration, Lanxide process). Hand lay-up processes – Spray up processes, Compression moulding, Reinforced reaction injection moulding, Resin transfer moulding, Pultrusion, Filament winding, Injection moulding. **Practical component:** Resin transfer moulding of composites **Suggested Readings:** Fundamentals of Composite Manufacturing	**CO-2** **BTL-2**
MODULE 3: MECHANICS OF COMPOSITE MATERIALS	**(12)**
Continuous fibres – iso-stress and iso-strain conditions, discontinuous fibres, Nature of stress vs. strain curves for different composite materials. Mechanical Properties: Mechanical testing of composites – tensile, flexure, bend tests, interfacial tests of laminates; Modes of fracture; Toughening mechanisms in composites. Self-healing composites, Molecular composites, Micro and Nanocomposites, Biocomposites, Left handed composites, Stiffer than stiff composites, Carbon / carbon composites, Advantages and limitations of carbon matrix. **Practical components**: Mechanical testing of Polymer matrix composites **Suggested Readings:** Mechanical properties of Composites	**CO-3** **BTL-2**
MODULE 4: SMART MATERIALS	**(12)**
Overview of smart materials, Classification of Smart Materials. Crystal Structure and Microstructure. Piezoelectric and Electrostrictive materials, Magnetostrictive and Magnetoelectric materials, Shape Memory Alloys, Optical fibre. Mechanics of smart composite materials, Smart sensors based on high bandwidth low strain smart materials, Low-bandwidth high strain smart actuators, Bimorphic accelerators, Intelligent devices based on smart materials. **Practical components**: Synthesis of Smart Materials for sensors **Suggested Readings:** Nanocomposite	**CO-4** **BTL-2**
MODULE 5: APPLICATION OF SMART MATERIALS	**(12)**

Smart materials for future, Photochromic and thermochromic, self-healing paints. Structural health monitoring of smart materials, Smart Fabrics, Application of smart materials in Civil, Automobile, Aero, mechanical, biomedical Engineering. Applications in electronic devices, Sensors and Robotics. **Practical components**: Synthesis of self-healing paints **Suggested Readings:** Smart material Systems	**CO-5** **BTL-3**

TEXT BOOKS	
1	Françoise Candau, Ronald H. Ottewill, "An introduction to polymer colloids", 2005. Springer Berlin Heidelberg, New York. ISBN: 9780792306009
2	A. D. Pomogailo and V. S. Savostyanov, "Synthesis and polymerization of metal containing monomers", 2017, CRC press. ISBN: 9781351077057
3	Vikas Mittal, "Polymer Nanocomposite Foams", 2018, CRC press. ISBN: 9781138074996
REFERENCE BOOKS	
1	Luigi Nicolais and Gianfranco Carotenuto, "Metal-Polymer Nanocomposites", 2004, Wiley Publisher. ISBN: 9780471695424
2	Anatolii D. Pomogailo and Vladimir N. Kestelman. "Metallopolymer Nano-composites", 2016, Springer (Heidelberg Springer Series in Materials Science) Berlin. ISBN: 9783540209492
E-BOOKS	
1	Ed. Abu Nasar, "Smart Polymers and Composites", 2018, Material Research Forum LLC. ISBN 978-1-945291-47-0 http://dx.doi.org/10.21741/9781945291470-2
MOOC	
1	https://nptel.ac.in/courses/118102003/27
2	https://nptel.ac.in/courses/113105028/35

COURSE TITLE	**NANOELECTRONICS AND NANO-PHOTONICS**			**CREDITS**	**4**
COURSE CODE	**ANO02009**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**4-0-0-0**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Second Periodical Assessment**	**Seminar/ Assignments/ Project**	**Surprise Test / Quiz**	**Attendance**	**ESE**

15%	15%	10%	5%	5%	50%

Course Description	The main objectives of the course is to provide basic background knowledge application of nanoelectronics. The course will covers nanoelectronic devices including single electron devices, tunnelling devices, transistors, nanophotonics and flexible electronics
Course Objective	1. Understand the basic concept of nanoelectronics 2. Interpret single electron devices and nanoarchitectures 3. Demonstrate the basic concepts of tunnelling devices and transistors 4. Explain the importance of Photonic crystals and its application 5. Illustrate and interpret organic flexible electronic devices
Course Outcome	Upon completion of this course, the students will be able to 1. Use the ideas of advanced electronic devices at nanoscale. 2. Analyze the operation and design of single electronic devices. 3. Classify different type of transistors and tunnelling devices 4. Use the fundamentals of Nanophotonics, nanoscale photonic crystals and applications 5. Understand the concepts of Organic light emitting devices and flexible electronics

Prerequisites: Basic knowledge in physics

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	1	2	1	1	-	1	1
CO-2	3	1	2	1	1	-	1	1
CO-3	3	1	2	1	1	-	1	1
CO-4	3	1	2	1	1	-	1	1
CO-5	3	1	2	1	1	-	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: INTRODUCTION	**(12)**
Basics of Nanoelectronics – Band diagram of semiconductor structures (quantum well, quantum barrier, super lattice) – Types of transistor integration – photons interacting with electrons in solids- electron transport, materials for Nano electronics, Semiconductor and Carbon nanotubes **Suggested Readings:** Basics of Nanoelectronics	**CO-1 BTL-1&2**
MODULE 2: SINGLE ELECTRON DEVICES	**(12)**
Single electron Box - Single electron transistor (SET) technology-performance of single electron transistor –Single electron transistor circuit design –electrostatic data storage - Nano-computer architectures, quantum dot cellular automata (QCA), molecular circuits,	**CO-2 BTL-1 & 2**

application of Quantum mechanical systems for computation. Properties of Q bits, Quantum circuit model, Quantum gates **Suggested Readings:** Single electron transistor technology and nano-computer architectures	
MODULE 3: TUNNELING DEVICES AND TRANSISTORS	**(12)**
Quantum Mechanical Tunnel Devices -Tunnelling diode – tunnel resistance – resonant tunnelling diode (RTD) – Resonant tunnelling bipolar transistor – Tunnelling element technology - Short channel MOS Transistor – Split gate transistor – Electron wave transistor – electron spin transistor **Suggested Readings:** Diodes and transistors	**CO-3 BTL-2&3**
MODULE 4: NANOPHOTONICS	**(12)**
Materials and Fabrication techniques of Photonic bandgap Crystals: Semiconductors, amorphous and polymers, fabrication of photonic crystal structure (1D, 2D, 3D), optics in nano sized quantum wells and wires (periodic nanostructures), negative refractive index, microwave induced transport. Nano-scale photonic devices, couplers, waveguides. Liquid crystals and their applications at the nanoscale. **Suggested Readings:** Nano-scale photonic devices and its application	**CO-4 BTL-2&3**
MODULE 5: FLEXIBLE ELECTRONICS	**(12)**
Polymer electronics - Self assembling circuits – Optical molecular memories – Switches based on fullerenes and CNTs, Quantum well infrared photo detector - Organic light emitting devices (OLEDs), molecular switches, thermochromic switches, Motor molecules and biomimetic components, charge transfer complexes, molecular connections, contact issues, conducting polymers, light emitting polymers, polymer heterostructures, plastic FETs. **Suggested Readings:** Polymer electronics, OLEDS, switches and plastic FETs.	**CO-5 BTL-1&2**

TEXT BOOKS	
1	Wolf, E. L. Nanophysics and nanotechnology: An introduction to modern concepts in nanoscience. 2004, Weinheim: Wiley-VCH.
2	Hanson, G. W. Fundamentals of nanoelectronics. 2008, Upper Saddle River, N.J: Pearson/Prentice Hall.
3	S.O. Kasap "Optoelectronics and Photonics Principles and Practices, 2001, Pearson
REFERENCE BOOKS	
1	Goser, K., Dienstuhl, J., &Glösekötter, P. Nanoelectronics and nanosystems, 2004, Springer; 2004th edition
2	Karl Goser , From transistors to molecular and quantum devices, 2013, . Springer Science & Business Media
E-BOOKS	
1	Kumar, B.G., Prakash, K.S. Nanoelectronics and Photonics for Next-Generation Devices. 2021, Springer, Cham. https://doi.org/10.1007/978-3-030-40513-7_53
MOOC	

1	https://www.mooc-list.com/course/nanophotonic-modeling-edx

COURSE TITLE	**NANOSCALE MAGNETIC MATERIALS AND DEVICES**			**CREDITS**	**4**
COURSE CODE	**ANO02010**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-0-2-0**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL-3**

ASSESSMENT SCHEME

First Periodical Assessment	Second Periodical Assessment	Seminar/ Assignments/ Project	Surprise Test / Quiz	Attendance	ESE
15%	15%	10%	5%	5%	50%

Course Description	The main objective of this course is to introduce the fundamentals of magnetic materials. It covers all areas of nanomagnetism. The course focuses on the fabrication and characterization of nanomagnets. It explains the different application of magnetic materials.
Course Objective	1. To understand the fundamentals of nanoscale magnetic materials. 2. To understand the concept of nanomagnetism in different models 3. To classify different types of magnetic nanostructures and their applications 4. To identify magnetic properties using different characterization tools 5. To perceive the different applications of magnetic materials
Course Outcome	Upon completion of this course, the students will be able to 1. Know the basics and importance of nanoscale magnetic parameters. 2. Understand the science and technology underlying the magnetic behaviour of nanostructures. 3. Realize the different forms of nanomagnetic materials and its applications. 4. Comprehend the methods of tuning the magnetic properties and its characterization. 5. Learn the diverse application of magnetic materials

Prerequisites: To have basic knowledge in physics

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PSO-1	PSO-2	PSO-3
CO-1	3	-	1	1	1	-	1	-	1	1

CO-2	**3**	**-**	**1**	**1**	**1**	**-**	**1**	**-**	**1**	**1**
CO-3	**3**	**-**	**1**	**1**	**1**	**-**	**1**	**-**	**1**	**1**
CO-4	**3**	**-**	**1**	**1**	**1**	**-**	**1**	**-**	**1**	**1**
CO-5	**3**	**-**	**1**	**1**	**1**	**-**	**1**	**-**	**1**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: INTRODUCTION	**(12)**
Fundamentals –Antiferromagnetic materials – Domains and the magnetization process– Coercivity of fine particles – Superparamagnetism in fine particles – Electron transport in magnetic multi-layers – Spin polarized electron tunnelling – Interlayer exchange coupling – Spin relaxation in magnetic metallic layers and multi-layers **Suggested Readings:** Fundamentals of magnetic property	**CO-1** **BTL-2**
MODULE 2: NANOMAGNETISM	**(12)**
Two-spin channel model - Two terminal spin electronics – Three terminal spin electronics - Spin tunnelling - Study of ferromagnetic and antiferromagnet interfaces – Photoemission Electron Microscopy - X-ray Absorption Spectroscopy - X-ray Magnetic Linear Dichroism (XMLD) - X-ray Magnetic Circular Dichroism (XMCD) **Suggested Readings:** Nano magnetism	**CO-2** **BTL-2&3**
MODULE 3: MAGNETIC STRUCTURES AND APPLICATIONS	**(12)**
Magnetic sensors and Giant Magnetoresistance - Optically transparent materials - Soft ferrites- Nanocomposite magnets - Magnetic refrigerant – High TC superconductor – Ferro/biofluids– Biomedical applications of magnetic nanoparticles - Diagnostic applications - Therapeutic applications - Physiological aspects - Toxic effects **Suggested Readings:** Application of magnetic material	**CO-3** **BTL- 2&3**
MODULE 4: FABRICATION AND IMAGING	**(12)**
Molecular nanomagnets – Mesoscopic magnetism - Particulate nanomagnets – Geometrical nanomagnets – Fabrication techniques scaling – Characterization using various techniques – Imaging magnetic microspectroscopy – Optical Imaging – Lorentz Microscopy – Electron Holography of Magnetic Nanostructures –Magnetic Force Microscopy. **Suggested Readings:** Magnetic microspectroscopy	**CO-4** **BTL-2&3**

MODULE 5: MAGNETIC DATA STORAGE AND RECORDING	(12)
Magnetic data storage – Disk formatting – Partitioning – Hard disk features – Hard disk data transfer modes – Programmed I/O – Direct memory access – Ultra DMA – Data addressing – Standard CHS addressing – Extended CHS addressing – Logical Block Addressing – Magnetic recording- Principles of magnetic recording - Magnetic digital recording - Perpendicular recording - Magneto-Optic recording - Magnetic media – Kerr effect – Faraday effect **Suggested Readings:** magnetic data storage	**CO-5** **BTL-2&3**

TEXT BOOKS	
1	Hans .P.O, and Hopster. H, "Magnetic Microscopy of Nanostructures", 2004. Springer. ISBN: 978-3642072864
2	Bland. J.A.C, and Heinrich. B, "Ultra-thin Magnetic Structures III – Fundamentals of Nanomagnetism", 2004, Springer, ISBN: 9783540219538
3	Nicola. A.S, "Magnetic Materials: Fundamentals and Device Applications", 2003, Cambridge University Press. ISBN: 978-0521816311
REFERENCE BOOKS	
1	Mohsen Shahinpoor, "Magnetic Nanomaterials", 2017, Royal Society of Chemistry. ISBN: 9781782627883
E-BOOKS	
1	JP Liu, "Nanoscale Magnetic Materials and Applications", 2009, springer, ISBN: 978-0-387-85598-1 https://link.springer.com/book/10.1007/978-0-387-85600-1
MOOC	
1	https://onlinecourses.nptel.ac.in/noc23_ee67/preview

COURSE TITLE	SYNTHESIS AND CHARACTERIZATION OF NANOMATERIALS -II			CREDITS	2
COURSE CODE	ANO02401	COURSE CATEGORY	PC	L-T-P-S	0-0-4-0
Version	1.0	Approval Details		LEARNING LEVEL	BTL-4
ASSESSMENT SCHEME					

Experimental	Analysis	Result	Viva	Record	ESE
20%	10%	10%	10%	10%	40%

Course Description	On successful completion of the course the students should have learnt about the fabrication of thin film by various methods and study the optical, electrical and morphological properties.
Course Objective	1. To synthesize metal oxides nanoparticles using chemical method. 2. To fabricate thin film by various techniques 3. To synthesize conducting polymers and measure the electrical properties 4. To determine photocatalytic efficiency of nanomaterials 5. To evaluate the electrochemical performance of energy storage materials.
Course Outcome	Upon completion of this course, the students will be able to 1. To synthesize nanomaterials metal oxides 2. Able to fabricate thin film by various methods 3. Determine the electrical property by using hall effect measurement 4. Examine the photocatalytic efficiency of nanomaterials 5. Evaluate impedance analyser and battery tester

Prerequisites: Knowledge of chemistry in undergraduate level.

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	3	2	1	1	3	1	1
CO-2	3	3	2	1	1	3	1	1
CO-3	3	3	2	1	1	3	1	1
CO-4	3	3	2	1	1	3	1	1
CO-5	3	3	2	1	1	3	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 2: LIST OF EXPIRIMENTS (45L)

1. Synthesis of Hydroxyapatite by Sol-gel method.	**CO-1 BTL-3**
2. Fabrication of scaffolds using freeze drying method	**CO-1 BTL-3**
3. Fabrication of Magnesium oxide thin film coating by spin coating technique.	**CO-2 BTL-3**
4. Fabrication of metal oxide thin film using chemical vapour deposition.	**CO-2 BTL-3**
5. Fabrication of metal thin films using thermal vacuum coating unit.	**CO-3 BTL3**
6. Synthesis of polyaniline (PA) thin film by SILAR method and Hall effect measurement	**CO-3 BTL-3**
7. To optimize the concentration of nanoparticles using UV-vis spectroscopy	**CO-4 BTL-4**
8. Evaluation of photocatalytic degradation efficiency of a give nanomaterial against organic dye	**CO-4 BTL-4**
9. Evaluation of oxidation and reduction potential using Cyclic voltammetry	**CO-5 BTL 4**
10. Determination of charge storage efficiency, energy density of a given nanomaterials based supercapacitor	**CO-5 BTL-4**

TEXT BOOKS

1.	Terje A, Conjugated Polymers, Theory, Synthesis, Properties, and Characterization, 2006, CRC press
2.	Yasir Beeran Pottathara, Nanomaterials Synthesis Design, Fabrication and Applications, 2019, Elsevier

REFERENCE BOOKS

1.	Dr. B. K. Sharma, Instrumental Methods of Chemical Analysis, 1981, GOEL publishing
2.	Milan Paunovic, Fundamentals of Electrochemical Deposition, Second Edition, 2005, Wiley publications
E BOOKS	
1.	https://pubs.acs.org/doi/abs/10.1021/ed008p1009.2
MOOC	
1.	https://www.mooc-list.com/tags/chemistry

SEMESTER- III

COURSE TITLE	**CARBON BASED NANOSTRUCTURES AND APPLICATIONS**			**CREDITS**	**4**
COURSE CODE	**ANO02011**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-0-2-0**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL 3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Second Periodical Assessment**	**Seminar/ Assignments/ Project**	**Surprise Test / Quiz**	**Attendance**	**ESE**
15%	**15%**	**10%**	**5%**	**5%**	**50%**

Course Description	This course is designed to reveal the unique geometrical and electronic structure of carbon nanotubes, graphene and familiarize the student with the current research in the field of carbon nanotubes including growth, synthesis techniques and device applications.
Course Objective	1. To identify different allotropes of carbon. 2. To classify various properties and synthesis methods of CNT 3. To explain the applications of 2D carbon based nanostructures in various fields. 4. To summarize applications of carbon nanostructures in medical field 5. To impart the role of carbon nanostructures in electronics and energy storage systems.
Course Outcome	Upon completion of this course, the students will be able to 1. Describe the basics of carbon in reduced dimensions 2. Compare various synthesis methods of carbon nanotubes and their advantages 3. Able to interpret the properties and applications of low dimensional carbonaceous materials. 4. Identify the role of carbonaceous materials in biomedical field 5. Illustrate the importance of carbon nanotubes in electronics and energy storage devices.

Prerequisites: Basics of nanomaterials, carbon molecules and its allotropes

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	2	1	1	1	1	1	1	1
CO-2	3	1	2	3	2	3	3	2
CO-3	3	2	3	3	2	3	2	1
CO-4	3	2	3	3	2	3	2	1
CO-5	3	2	3	3	2	3	2	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: CARBON NANO SCIENCE (12)

Introduction - Carbon molecules, Carbon allotrope nature of the carbon bond, new carbon structures, Graphene - From a Graphene Sheet to a Nanotube, Single Wall Carbon Nanotubes (SWCNT), Multi Wall Carbon Nanotubes (MWCNT) - Armchair, Zigzag and Chiral Nanotubes. **Practical component:** Synthesis of graphene oxide **Suggested Readings:** Basics of carbon molecule and its allotropes	**CO-1** **BTL-1 & 2**

MODULE 2: PROPERTIES AND SYNTHESIS OF CARBON NANOTUBES (12)

Properties of CNT – optical, mechanical, vibrational, thermal, electrical and electronic properties of CNT, Raman spectroscopy of CNTs, Synthesis of CNT - Arc discharge, Laser ablation, Chemical vapour deposition. **Practical component:** Optical properties of carbon nanotube **Suggested Readings:** Properties of CNT	**CO-2** **BTL-2&3**
MODULE 3: 2D CARBONACEOUS NANOSTRUCTURES	**(12)**
Introduction of graphene, Types of graphene: stacking AA, BB, AB dispersion relation, Single layer, Bi-layer, Few layers, Properties of graphene; Optical: thickness dependency, optical conductivity, electric filed tunable transparency, Electrical: Boltzmann equation, ambipolar conduction, density of states and doping, quantum hall effect, Klein tunnelling, diamagnetism, thermal conductivity. Mechanical, Surface phenomenon. **Practical component:** Optical conductivity of graphene **Suggested Readings:** Properties of Graphene	**CO-3** **BTL-1 &3**
MODULE 4: BIOMEDICAL APPLICATIONS	**(12)**
Artificial implant scopes, Tissue engineering, Cancer cells tracing, Gene and drug delivery applications, bio medical sensors, Regenerative engineering, Bio imaging, Graphene medical devices and Hygiene products, Antimicrobial applications. **Practical component:** Graphene coating on cloth for medical application **Suggested Readings:** Medical implants, drug delivery and basics of sensors.	**CO-4** **BTL- 2 &3**
MODULE 5: APPLICATION IN ELECTRONICS AND ENERGY STORAGE	**(12)**
Nanochip, CNT FETs, Light emitting displays and flat panel displays, optical and telecommunication applications, fuel cells, Graphene and CNT based supercapacitors, rechargeable batteries, solar panels, application of CNT and Graphene in clean energy – hydrogen production and storage. **Practical component:** Fabrication of carbon based supercapacitor **Suggested Readings:** Light emitting diodes, hydrogen storage	**CO-5** **BTL-2&3**

TEXT BOOKS	
1	Charles P. Poole and Frank J. Owens, Introduction to Nanotechnology, (2003) Wiley India Pvt Ltd. 1 st edition, ISBN -10: 0471079359
REFERENCE BOOKS	
1	Jiji Abraham, Sabu Thomas, Nandakumar Kalarikkal Handbook of Carbon Nanotubes, (2002), Springer Cham 1st edition, ISBN 978-3-030-91345-8

2	T. Pradeep, Nano: The Essentials – Understanding Nano Science and Nanotechnology, (2007), Tata McGraw Hill, 1st edition, ISBN: 9780071548298
E BOOKS	
1	Michael J, O'Connell, Carbon Nanotubes: Properties and Applications, Kindle Edition, CRC Press, 1st edition, ISBN-13 978-0849327483
MOOC	
1	https://www.edx.org/course/graphene-science-and-technology

COURSE TITLE	**MICRO AND NANOFABRICATION**			**CREDITS**	**4**
COURSE CODE	**ANO02012**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**3-0-2-1**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Second Periodical Assessment**	**Seminar/ Assignments/ Project**	**Surprise Test / Quiz**	**Attendance**	**ESE**
15%	**15%**	**10%**	**5%**	**5%**	**50%**
Course Description	The main objective of this course is to introduce technology and processes that are used in fabricating advanced electronic devices and circuits. It covers all areas of micro and nanofabrication device processing, including substrates, cleaning, native films growth, Lithography techniques, STM, AFM techniques. This course also focus on the recent progress of MEMS and NEMS technology and applications.				
Course Objective	1. To understand the concepts of semiconductors and clean room process 2. To Classify different types of lithography techniques 3. To conceptualize surface patterning techniques. 4. To interpret nano manipulation processes and characterization techniques. 5. To comprehend the concepts of NEMS and MEMS				
Course Outcome	Upon completion of this course, the students will be able to 1. Understand the fundamentals of semiconductors and clean room processing methods 2. Appraise the working principle and instrumentation of lithography techniques 3. Understand the basic concepts different surface patterning techniques 4. Interpret nano manipulation process with respective tools				

	5. Sketch the NEMS modelling, simulation, actuators and FET technology.

Prerequisites: To have basic knowledge in physics

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	-	2	1	2	-	-	-
CO-2	3	-	2	1	2	2	1	1
CO-3	3	-	2	1	2	2	1	1
CO-4	3	-	2	1	2	2	1	1
CO-5	3	-	2	1	2	2	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: Clean Room and Process Integration	**(12)**
Clean Rooms: Clean room Standards-Clean room sub-systems-Environment Safety And Health Aspects-Oxidation – Lithography – Etching- Diffusion Process Integration: Junction and Oxide Isolation – Substrates – Contacts - Metallization - Planarization and Advanced Interconnect. **Practical component:** Etching process of Si and Sapphire substrate **Suggested Readings:** Diffusion process integration, Schottky contacts and Ohmic contacts	**CO-1** **BTL-2&3**
MODULE 2: OPTICAL LITHOGRAPHY	**(12)**
Introduction – EUV lithography, photolithography and different types- UV, Deep UV, Extreme UV and X-ray lithography , Electron Beam lithography, Direct Write Lithography – Focused ion beam (FIB) lithography – Neutral atomic beam lithography – Soft Lithography. **Practical component:** Virtual Lab: EUV Lithography **Suggested Readings:** Lithography techniques	**CO-2** **BTL-3**
MODULE 3: SURFACE PATTERNING	**(12)**
Preparing and patterning surfaces, Manipulation and patterning of surfaces, Surface patterning techniques- Nano patterning- surface, chemical, topographical, combinatorial, and 3D patterning. Micro contact printing, Nano sphere Lithography. Nanoimprint – Dip-pen nanolithography. **Practical component:** Virtual Lab: Nano Patterning **Suggested Readings:** Patterning techniques	**CO-3** **BTL-3**
MODULE 4: NANOMANIPULATION AND PROCESSING	**(12)**
Scanning tunnelling microscopy (STM) – Atomic force microscopy (AFM) – Near-field scanning optical microscopy (NSOM) – Advanced Techniques: Embossing and surface passivation, Dimensional Subtraction and Addition, Multistep Processing, of –Micro contact printing– Molding – implications and applications of the conventional and advanced techniques.	**CO-4** **BTL-3**

Practical component: Virtual Lab: Atomic Force Microscope (AFM) **Suggested Readings:** STM, AFM and NSOM techniques	
MODULE 5 MEMS & NEMS TECHNIQUES	**(12)**
MEMS materials and challenges, rigid body dynamics, electrostatic forces, electromagnetic forces, electricity, fluid mechanics, heat transfer. MEMS future and applications, microsystems and microelectronics-Recent trends in MEMS. Introduction to NEMS and its architecture - carbon nanotube electronics - modelling - analysis and simulation - simulation of Actuators, FET, Pressure transducer - applications and future challenges **Practical component:** Simulation of MEMS lab in nanoHUB.org **Suggested Readings:** MEMS & NEMS techniques and applications	**CO-5** **BTL-3**

TEXT BOOKS	
1	Guozhong Cao, "Nanostructures & Nanomaterials Synthesis, Properties Applications", 2004, World Scientific Publishing Private Ltd. ISBN:9789814322508
2	Zheng Cui, "Nanofabrication, Principles, Capabilities and Limits", 2008, Springer Science business media. ISBN: 978-1441945365
3	Syergey Edward Lyshevski, "MEMS and NEMS systems, Devices and Structures", 2002, CRC Press, New York. ISBN: 978-0849312625
REFERENCE BOOKS	
1	Tai-Ran Hsu, "MEMS and Microsystems Design and Manufacture", 2002, Tata Mcraw Hill. ISBN: 9780072393910
2	James J Allen, "Micro Electro Mechanical System Design", 2005, CRC Press-Taylor & Francis‖, New York. ISBN: 9780429116865
3	Ananthasuresh G. K, Vinoy. K.J, Gopalakrishnan S, "Micro and Smart Systems", 2012,Wiley India Pvt Ltd, New Delhi. ISBN: 9788126527151
E-BOOKS	
1	Cornelius T. Leondes, "MEMS/NEMS - Handbook Techniques and Applications", 2006, Springer New York, NY. https://link.springer.com/book/10.1007/b136111
MOOC	
1	https://nptel.ac.in/courses/102108078

COURSE TITLE	**INTERNSHIP**			**CREDITS**	**4**
COURSE CODE	**ANO02800**	**COURSE CATEGORY**	**PC**	**L-T-P-S**	**0-0-0-0**

Version	1.0	Approval Details		LEARNING LEVEL	BTL-4
ASSESSMENT SCHEME					
CIA					**ESE**
60%					**40%**
Course Description	The internship will allow the students to prepare samples and devices for industrial applications and carry out processes to analyze structures at the nanometer scale, along with documenting the results of their work.				
Course Objective	1. To make the students develop the nanoparticles, nanoscale devices, problem techniques in various industrial fields. 2. To gain knowledge on advantages of nanotechnology based applications in each industry. 3. To make familiar instances of contemporary industrial applications of nanotechnology. 4. To provide an overview of future technological advancements and increasing role of nanotechnology in each industry.				
Course Outcome	Upon completion of this course, the students will be able to 1. Conceive a problem statement either from rigorous literature survey or from the requirement raised by external entity during the Internship initial discussion. 2. Hands-on experience on number of characterization techniques. 3. Able to write the document report in form of .doc and .pptx. 4. Present the work done and report submission.				
Prerequisites: Basics of nanomaterials and nanodevices.					

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	3	3	3	3	3	3	3
CO-2	3	3	3	3	3	3	3	3
CO-3	3	3	3	3	3	3	3	3
CO-4	3	3	3	3	3	3	3	3

1: Weakly related, 2: Moderately related and 3: Strongly related

COURSE TITLE	PROJECT PHASE-I			CREDITS	4
COURSE CODE	ANO02801	COURSE CATEGORY	PC	L-T-P-S	0-0-8-0
Version	1.0	Approval Details		LEARNING LEVEL	BTL-5

ASSESSMENT SCHEME

CIA	ESE
60%	40%

Course Description	Students in consultation with the guide/s shall carry out literature survey/visit industries to finalize the topic of the Project. Subsequently, the students shall collect the material required for the selected project, prepare synopsis and narrate the methodology to carry out the project work.
Course Objective	1. To make the students, a sound scientific knowledge of their selected project topic. 2. To expose the students and train them on problem identification, formulation and solution. 3. To make the students design solutions to complex problems. 4. To expose the students and train them on interpretation of the results. 5. To make the students, a sound knowledge in research paper writing and presentation.
Course Outcome	Upon completion of this course, the students will be able to 1. Demonstrate a sound scientific knowledge of their selected project topic. 2. Undertake problem identification, formulation and solution. 3. Design solutions to complex problems utilizing a scientific approach. 4. Communicate with scientists and the community at large in written an oral forms. 5. Demonstrate the knowledge, skills and attitudes of a researcher.

Prerequisites: Knowledge of Chemistry in undergraduate level.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	1	1	3	1	1
CO-2	3	3	1	1	1	3	1	1
CO-3	3	3	1	1	1	3	1	1
CO-4	3	3	1	1	1	3	1	1
CO-5	3	3	1	1	1	3	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

Semester – IV

COURSE TITLE	PROJECT PHASE-II + DISCUSSION			CREDITS	14
COURSE CODE	ANO02802	COURSE CATEGORY	PC	L-T-P-S	0-0-28-0
Version	1.0	Approval Details		LEARNING LEVEL	BTL-5
ASSESSMENT SCHEME					
CIA					ESE
60%					40%
Course Description	The project phase-II will include several of the following components: planning and carrying out a research project in nanotechnology, based on literature survey and preliminary results gained in the Project Phase-I, Production of data, structuring and adequate interpretation of them; setting up and testing hypotheses; finding and making uses of new literature; writing a research project report.				
Course Objective	1. To make the students, a sound scientific knowledge of their selected project topic. 2. To expose the students and train them on problem identification, formulation and solution. 3. To make the students design solutions to complex problems. 4. To expose the students and train them on interpretation of the results. 5. To make the students, a sound knowledge in research paper writing and presentation.				
Course Outcome	Upon completion of this course, the students will be able to 1. Demonstrate a sound scientific knowledge of their selected project topic. 2. Undertake problem identification, formulation and solution. 3. Design solutions to complex problems utilizing a scientific approach. 4. Communicate with scientists and the community at large in written an oral forms.				

	5. Demonstrate the knowledge, skills and attitudes of a researcher.

Prerequisites: Knowledge of Chemistry and scientific exposure of Project Phase-I.

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	3	1	1	1	3	1	1
CO-2	3	3	1	1	1	3	1	1
CO-3	3	3	1	1	1	3	1	1
CO-4	3	3	1	1	1	3	1	1
CO-5	3	3	1	1	1	3	1	1

1: Weakly related, 2: Moderately related and 3: Strongly related

Department Electives – Semester III

COURSE TITLE	ENVIRONMENTAL NANOTECHNOLOGY			CREDITS	3
COURSE CODE	ANO02501	COURSE CATEGORY	DE	L-T-P-S	3-0-0-0
Version	1.0	Approval Details		LEARNING LEVEL	BTL-3

ASSESSMENT SCHEME

First Periodical Assessment	Second Periodical Assessment	Seminar/ Assignments / Project	Surprise Test / Quiz	Attendance	ESE
15%	15%	10%	5%	5%	50%

Course Description	This course provides a brief discussion about various nanomaterials for photo catalysis and remediation. The application of nanomaterials as adsorbent to purify water is discussed. Various membrane technology is discussed. The toxicological aspect of nanomaterial is discussed.

Course Objective	1. To understand photo catalytic properties of nanomaterials 2. To demonstrate nanomaterials as adsorbents 3. To introduce various membrane technology. 4. To identify the toxicological impacts of nanomaterials. 5. To elucidate ecotoxicological impacts of nanomaterials
Course Outcome	Upon completion of this course, the students will be able to 1. Describe the mechanism of photo catalysis and remediation using nanomaterials 2. Demonstrate the application of nanomaterial as adsorbent 3. Indicate the various membrane processes 4. Identify the toxicological Impacts of Nanomaterials 5. Describe about Ecotoxicological Impacts of Nanomaterials

Prerequisites: Knowledge about environmental science

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	3	1	2	3	3	3	3	3
CO-2	3	1	2	3	3	3	3	3
CO-3	3	1	2	3	3	3	3	3
CO-4	1	1	-	-	-	-	-	-
CO-5	1	1	-	-	-	-	-	-

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: NANOMATERIAL AS PHOTOCATALYST	**(12)**
Photocatalysis: fundamentals, processes and mechanism - Semiconductors-Zinc oxide, Titanium oxide, Iron oxide, gadolinium oxide, antimony oxide – nanocomposite. Nanomaterial photocatalysts for water splitting to provide clean fuel resources- Photocatalysis using nanomaterials for CO_2 reduction in the environment. Nanomaterials used in photocatalysis for removing environmental pollutants- Photocatalysis using nanomaterials for self-decontaminating surfaces- Factors affecting the activity of nanomaterial photocatalysts.-Bioremediation of environmental pollutants using nanomaterials in the presence/absence of light and their impacts on the eco-system.	**CO-1 BTL-2 &3**

Suggested Readings: Nanomaterial as photo catalyst	
MODULE 2: ENVIRONMENTAL REMEDIATION	**(12)**
Adsorption phenomena- Adsorption isotherm models-kinetic model- Nanomaterial-Based Adsorbents for Water and Wastewater Treatment. Adsorption at the Oxide Nanoparticles/Solution Interface-Carbon based adsorbents- (activated carbon, Carbon aerogel graphene, MWCNT), Metal oxide-based nanomaterials, nanocomposites - porous nanostructures **Suggested Readings:** Adsorption phenomena	**CO-2 BTL-2**
MODULE 3: MEMBRANE PROCESSES	**(12)**
Overview of Membrane Processes-Transport Principles for Membrane Processes-Membrane Fabrication Using Nanomaterials- Nanoparticle Membrane Reactors. Active Membrane Systems. Oxide Nanomembranes, Magnetic Nanomembranes, Polymer Nanomembranes, Biological and Biomimetic Nanomembranes, Nanomembranes from 2D Materials, Composite Nanomembranes **Suggested Readings: Membrane processes**	**CO-3 BTL-2 & 3**
MODULE 4: TOXICOLOGICAL IMPACTS OF NANOMATERIALS	**(12)**
Fullerenes, Single-Walled Carbon Nanotubes (SWCNT), Multi-Walled Carbon Nanotubes (MWCNT)- Complications in Screening Assays Using Carbon-Based Materials- Titanium Dioxides- Iron Oxides- Cerium Dioxides-Copper Nanoparticles-Gold Nanoparticles-Quantum Dots-Exposure and Risk Assessment- Environmental Impact **Suggested Readings:** Toxicological Impacts of Nanomaterials	**CO-4 BTL-2**
MODULE 5: ECOTOXICOLOGICAL IMPACTS OF NANOMATERIALS	**(12)**
Methods to Assess Ecotoxicity- Bioavailability and Cellular Uptake of Nanoparticles. Antibacterial Activity of Nanomaterials- Biotransformation of Nanomaterials by Microbes- Factors Mitigating Nanomaterial/ Organismal Interactions **Suggested Readings:** Ecotoxicological Impacts of Nanomaterials	**CO-5 BTL-2**
TEXT BOOKS	
1	

	W. D. Callister, "Materials Science and Engineering: An Introduction", 2018 John Wiley & Sons, ISBN: 978-1-119-40549-8
REFERENCE BOOKS	
1	Mark R. Wiesner, Jean-Yves Bottero, Environmental Nanotechnology: Applications and Impacts of Nanomaterials, 2007, The McGraw-Hill Companies,
2	Yongfeng Mei , Gaoshan Huang , Xiuling Li, Nanomembranes: Materials, Properties, and Applications, 2022, Wiley Publication,
E-BOOKS	
1	Dasgupta, Nandita, Ranjan, Shivendu, Lichtfouse, Environmental nanotechnology, 2019, Volume 2 Springer
MOOC	
1	https://nptel.ac.in/courses/113104058/mme_pdf/Lecture1.pdf

COURSE TITLE	**IOT BASED SENSORS**			**CREDITS**	**3**
COURSE CODE	**ANO02502**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**3-0-0-0**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment	**Second Periodical Assessment**	**Seminar/ Assignments/ Project**	**Surprise Test / Quiz**	**Attendance**	**ESE**
15%	**15%**	**10%**	**5%**	**5%**	**50%**
Course Description	The Internet of Things (IOT) is defined as the network of physical objects, things that are embedded with sensors, actuators, software and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. This program aims to train students to be equipped with a solid theoretical foundation about sensors and actuators. After doing this course, students should be able to understand how information from physical devices in the real world gets communicated to Smartphone processors. This course covers different sensor technology and its fabrication methods and application.				

Course Objective	1. To understand the fundamentals of IOT 2. To Introduce evolution of internet technology and need for IoT in various application 3. To interpret the basic concepts and application of sensors 4. To classify different types of sensors 5. To describe the types of gas sensors and their mechanism
Course Outcome	Upon completion of this course, the students will be able to 1. Understand the importance and applications of IoT 2. Identify the sensors and other devices needed for different IoT solutions 3. Understand the principle, characteristics of sensors 4. Compare and classify different types of IoT based sensors 5. Interpret the mechanism of various IoT based sensors

Prerequisites: Use Internet of Things (IOT) to enable combination of nanosensors for real world applications

CO, PO AND PSO MAPPING

CO	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**1**	**1**	**2**	**2**	**2**	**1**	**1**	**1**
CO-2	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**
CO-3	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**2**
CO-4	**1**	**2**	**2**	**2**	**1**	**1**	**2**	**2**
CO-5	**1**	**2**	**2**	**2**	**1**	**1**	**2**	**2**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: FUNDAMENTAL CONCEPTS OF IOT	**(12)**
Introduction, Definitions & Characteristics of IoT, IoT Architectures, Physical & Logical Design of IoT, Enabling Technologies in IoT, History of IoT, About Things in IoT, The Identifiers in IoT, About the Internet in IoT, IoT frameworks, IoT and M2M. Wireless Technologies for IoT - WPAN Technologies for IoT: IEEE 802.15.4, Zigbee, HART, NFC, Z-Wave, BLE, Bacnet, Modbus **Suggested Readings:** Physical & Logical Design of IoT	**CO-1 BTL- 2**
MODULE 2: APPLICATION AND IP BASED PROTOCOLS FOR IOT	**(12)**
Home Automation, Smart Cities, Energy, Retail Management, Logistics, Agriculture, Health and Lifestyle, Industrial IoT, Legal challenges, IoT design Ethics, IoT in Environmental Protection. IP Based Protocols for IoT - IPv6, 6LowPAN, RPL, REST, AMPQ, CoAP, MQTT. Edge connectivity and protocols **Suggested Readings:** IP Based Protocols for IoT	**CO-2 BTL- 2 & 3**
MODULE 3: TYPES OF SENSORS	**(12)**

Types of sensors- Position, Motion, Velocity and Acceleration ,Force, Pressure, Flow, Humidity, Light, Radiation, Temperature, Image, Gas, Ultrasonic, Infrared Sensors, Micro and Nano sensors. Criteria to choose a sensor. Bio sensor - Nanoparticle-Based Electrochemical Biosensors –DNA enabled biosensors - CNT-Based Electrochemical Biosensors - Functionalization of CNTs for Biosensor Fabrication Quantum Dot-Based Electrochemical Biosensors - Nanotube- and Nanowire-Based FET Nano biosensors - Cantilever-Based Nano biosensors - Optical Nano biosensors **Suggested Readings:** CNT based Biosensors	**CO-3** **BTL-2 & 3**
MODULE 4: IOT BASED SENSORS	**(12)**
Working Principle of Sensors, Sensor Characteristics, Classification of Sensors, Difference between sensor, transmitter and transducer - Primary measuring elements - selection and characteristics: Range; resolution, Sensitivity, error, repeatability, linearity and accuracy, impedance, backlash, Response time, Dead band. Signal transmission - Types of signal. Application of sensors. Fabrication of Sensor - Electrode fabrication: Screen printing, Photolithography, Electroplating Sensing film deposition: Physical and chemical Vapor, Anodization. **Suggested Readings:** Principle, fabrication, properties and application of sensors	**CO-4** **BTL-2 & 3**
MODULE 5: CHEMOSENSORS	**(12)**
Gas Sensing with Nanostructured Thin Film, Adsorption on Surfaces, Conductometric transducers suitable for Gas Sensing, Gas Reaction on the Surface, Effect of Gas Sensitive Structures and Thin Films- Metallic Nanoparticle Based Gas Sensors - Metal Oxide Gas Sensors - Carbon Nanotube Gas Sensors - Porous Silicon-Based Gas Sensor - Organic Polymer Film–Based Gas Sensors - Nanosensor Arrays - Nanoelectronic Nose – Optochemical Nanosensors. Nanosensors Based on Surface-Enhanced Raman Scattering (SERS) - Colloidal Surface Plasmon resonance (SPR) Colorimetric Gold Nanoparticle Spectrophotometric Sensor. **Suggested Readings:** Mechanism of Chemosensors	**CO-5** **BTL-2 & 3**

TEXT BOOKS	
1	Olivier Hersent, David Boswarthick, and Omar Elloumi, — "The Internet of Things: Key Applications and Protocols", 2012, Wiley Publications
2	Nanosensors: Physical, Chemical and Biological, Vinod Kumar Khanna, 2012,CRC.
REFERENCE BOOKS	
1	Daniel Minoli, — "Building the Internet of Things with IPv6 and MIPv6: The Evolving World of M2M Communications", ISBN: 978-1-118-47347-4, Willy Publications
2	Pethuru Raj and Anupama C. Raman, "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", 2017, CRC Press

3	Kevin C. Honey church, Nanosensors for Chemical and Biological Applications: Sensing with Nanotubes, Nanowires and Nanoparticles,2014. Woodhead publishing
E-BOOKS	
1	https://www.elektor.com/internet-of-things-e-book
MOOC	
1	https://www.mooc-list.com/course/iot-sensors-and-devices-edx

COURSE TITLE	**MEMS AND NEMS**			**CREDITS**	**3**
COURSE CODE	**ANO02503**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**3-0-0-0**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL-3**

ASSESSMENT SCHEME

First Periodical Assessment	**Second Periodical Assessment**	**Seminar/ Assignments/ Project**	**Surprise Test / Quiz**	**Attendance**	**ESE**
15%	**15%**	**10%**	**5%**	**5%**	**50%**

Course Description	This course is designed to provide an understanding of MEMS and NEMS, as well as the modeling of micro and nano-scale electromechanical systems. The course will familiarize students with various types of sensors and will also cover future nanosystems.
Course Objective	1. To introduce Nano-and Microsystems 2. To understand the modeling of micro and nano scale electromechanical systems 3. To conceptualize organic and inorganic Sensors 4. To understand the Photoelectric Effect and magneto-optical phenomena 5. To identify and regonize the future Nanosystems.
Course Outcome	Upon completion of this course, the students will be able to 1. Acquire the knowledge of Nano-and Microsystems. 2. Identify the methods of modelling of micro and nano scale electromechanical systems 3. Classify organic and inorganic enabled sensors. 4. Learn various Physical effects of sensors. 5. Identify the future of Nanomachines

Prerequisites: Basic knowledge in Sensors

CO, PO AND PSO MAPPING

CO	**PO -1**	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PSO-1**	**PSO-2**	**PSO-3**

CO-1	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
CO-2	**3**	**1**	**2**	**3**	**2**	**3**	**3**	**2**
CO-3	**3**	**2**	**3**	**3**	**2**	**3**	**2**	**1**
CO-4	**3**	**2**	**3**	**3**	**2**	**3**	**2**	**1**
CO-5	**3**	**2**	**3**	**3**	**2**	**3**	**2**	**1**
1: Weakly related, 2: Moderately related and 3: Strongly related								

MODULE 1: INTRODUCTION TO MEMS AND NEMS (12)	
MEMS and NEMS definitions, Taxonomy of Nano-and Microsystems-Synthesis and Design. Classification and considerations, Biomimetics, Biological analogies, and design–Biomimetics Fundamentals, Biomimetics for NEMS and MEMS, Nano-ICs and Nanocomputer architectures **Suggested Readings:** MEMS AND NEMS	**CO-1 BTL-2**
MODULE 2: MODELING OF MICRO AND NANO SCALE ELECTROMECHANICAL SYSTEMS (12)	
Introduction to modelling, analysis and simulation, basic electro-magnetic with application to MEMS and NEMS, modeling developments of micro-and nano actuators using electromagnetic-Lumped-parameter mathematical models of MEMS, energy conversion in NEMS and MEMS **Suggested Readings:** Modelling Of Micro And Nano Scale Electromechanical System	**CO-2 BTL-2&3**
MODULE 3: INORGANIC AND ORGANIC ENABLED SENSORS (12)	
Introduction-types of sensors-Mechanical, optical, spintronic, bioelectronic and biomagnetic sensors-surface modification-surface materials and interactions and its examples **Suggested Readings:** Inorganic and Organic Enabled Sensors	**CO-3 BTL-2 & 3**
MODULE 4: SENSOR CHARACTERISTICS AND PHYSICAL EFFECTS (12)	
Introduction to sensors, static Characteristics and dynamic characteristics, Physical effects : - Photoelectric Effect, Photoluminescence Effect, Electroluminescence Effect , Chemiluminescence Effect, Doppler Effect , Hall Effect, thermoelectric effect, magneto-optical phenomena **Suggested Readings:** Sensor Characteristics	**CO-4 BTL-3**
MODULE 5: FUTURE NANOSYSTEMS (12)	
Nano machines, nano robots, electronics based on CNT, molecular Electronics. Quantum Computation: Future of Meso/Nanoelectronics -Interfacing with the Brain, towards molecular medicine, Lab-on-BioChips- Guided evolution for challenges and the solutions in NanoManufacturing technology. **Suggested Readings**: Light emitting diodes, hydrogen storage	**CO-5 BTL-2 & 3**
TEXT BOOKS	

1	Sergey Edward Lyshevski, Lyshevski Edward Lyshevski, Micro-Electro Mechanical and Nano-Electro Mechanical Systems, Fundamental of Nano-and Micro-Engineering 2005, 2nd Ed., CRC Press.
2	A. S. Edelstein and Cammarata, Nanomaterials: Synthesis, Properties and Applications,2002, Institute of Physics, Bristol, Philadelphia
REFERENCE BOOKS	
1	Zheng Cui, Nanofabrication, Principles, Capabilities and Limits, 2008, Springer
2	Kalantar–Zadeh K, Nanotechnology Enabled Sensors, 2008, Smpringer.
3	Serge Luryi, Jimmy Xu, Alex Zaslavsky, Future trends in Micro Electronics, 2007, John Wiley & Sons, Inc. Hoboken, New Jersey
E BOOKS	
1	Leondes**,** Cornelius T. (Ed.) MEMS/ NEMS Handbook Techniques and Application, 2006,Springer US
MOOC	
1	https://onlinecourses.nptel.ac.in/noc22_ee36/preview

COURSE TITLE	**NANOTECHNOLOGY IN HEALTH CARE**			**CREDITS**	**3**
COURSE CODE	**ANO02504**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-0**
Version	**1.0**	**Approval Details**		**LEARNING LEVEL**	**BTL-3**
ASSESSMENT SCHEME					
First Periodical Assessment (Theory + Practical)	**Seconds Periodical Assessment (Theory + Practical)**	**Weekly assignment/Observation / lab records as approved by DEC**	**Surprise Test / Quiz as approved by DEC**	**Attendance**	**ESE (Theory + Practical)**
15%	**15%**	**10%**	**5%**	**5%**	**50%**
Course Description	This course deals with the diverse application of nanobiotechnology in health care system. It covers the various types of nano molecular diagnostic tools. The course also covers about the nanomachines and nanobiosensors. The role of nanotechnology in biological therapies is discussed in detail. Emphasis of the applications of nanoscience and technology in pharmaceutical industry. The course covers various biopolymers and its application.				

Course Objective	1. To impart knowledge of applications in bionanotechnology in health care system. 2. To understand the principles of nano molecular diagnostic tools. 3. To explore nanomachines and nanobiosensors. 4. To learn different modes of application of nanomaterial in biological therapies. 5. To demonstrate the various biodegradable polymers and its applications
Course Outcome	Upon completion of this course, the students will be able to 1. Explain the principles of applications in bionanotechnology in health care system 2. Impart knowledge about principles of nano molecular diagnostic tools 3. Interpret the application of nanomaterials in nanomachines and nanobiosensors 4. Introduce the nanomaterials to pharmaceuticals 5. Conceptualize biodegradable polymers and their applications

Prerequisites: Basic knowledge in biology

CO, PO AND PSO MAPPING

	PO -1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO-1	**2**	**1**	**-**	**2**	**1**	**-**	**1**	**1**
CO-2	**2**	**1**	**-**	**2**	**1**	**-**	**1**	**1**
CO-3	**2**	**1**	**-**	**2**	**1**	**-**	**1**	**1**
CO-4	**2**	**1**	**-**	**2**	**1**	**-**	**1**	**1**
CO-5	**2**	**1**	**-**	**2**	**1**	**-**	**1**	**1**

1: Weakly related, 2: Moderately related and 3: Strongly related

MODULE 1: NANOMOLECULAR DIAGNOSTICS - ARRAY AND CHIPS (12)	
Introduction – Nano and Molecular Diagnostics-Self-Assembling Protein Nano arrays -Fullerene Photodetectors for Chemiluminescence Detection on Microfluidic Chips - Nano biochip -Gold Nanoparticles- Quantum Dots for Molecular Diagnostics Magnetic Nanoparticles -Use of Nanocrystals in Immunohistochemistry -Imaging Applications of Nanoparticles Study of Chromosomes. DNA–Protein and DNA–Nanoparticle Conjugates. **Suggested reading :** Nanotechnology for Diagnostics	**CO-1 BTL -2**
MODULE 2: NANOMACHINES and NANOBIOSENSORS (12)	
DNA Nanomachines for Molecular Diagnostics - Nanoparticle-Based Colorimetric DNA Detection Method Cantilevers as Biosensors for Molecular Diagnostics –Carbon Nanotube Biosensors -FRET-Based DNA Nano sensors. Electrochemical Nano biosensors -Quartz Nano balance Biosensors -Viral Nano sensors -PEBBLE Nano sensors -Microneedle-Mounted Biosensors Optical Biosensors-Nanoscale Erasable Bio-detectors **Suggested reading** : Nanomachines for Molecular Diagnostics	**CO-2 BTL-2 & 3**
MODULE 3: NANOPHARMACEUTICALS (12)	
Introduction –Nanobiotechnology for Drug Discovery -Gold Nanoparticles and Quantum Dots for Drug Discovery -Nanolasers for Drug Discovery -Cells Targeting by Nanoparticles -Role of AFM for Study of Biomolecular Interactions for Drug Discovery -	**CO-3 BTL 2**

Drug Development -Dendrimers and Fullerenes as Drug Candidates -Nanobodies - Trojan Nanoparticles - Liposome – Nanoparticle - Hybrids - Nanospheres - Nanotubes-Nanocochleates. Nanomolecular Valves for Controlled Drug Release **Suggested reading** : Nanopharmaceuticals	
MODULE4: ROLE OF NANOTECHNOLOGY IN BIOLOGICAL THERAPIES (12)	
Introduction - Development of nano medicines – Nano Shells – Nano pores – Tectodendrimers– Nanoparticle drug system for oral, nasal and ocular administration – Preformulation Studies: on various dosage forms such as tablets, capsules, suspension, creams, emulsion, injectables, ophthalmic and aerosols etc. Different types of drug loading – Drug release – Applications Nanobiotechnologies for Single-Molecule Detection - Point-of-Care, Diagnostics Battle Field- Therapeutics **Suggested reading** : nanomedicine	**CO-4 BTL-2**
MODULE 5: BIODEGRADABLE POLYMERS (12)	
Structure, function and application of natural materials: polypeptides –silk, collagen, Polysaccharides- cellulose,chitin, chitosan , starch, agarose, fibroin, sericin, keratins, gelatin, guar gum. polylactic acid(PLA), polyvinyl alcohol(PVA), polyglycolic acid, polycaprolactone, polyurethane, polycarbonate, polyamide, polydimethylsiloxane, polyethylene glycol, polybutylene succinate **Suggested reading** : Biodegradable polymers	**CO-5 BTL-2**

TEXT BOOKS	
1	Kewal. K, Jain ," *The Handbook of Nanomedicine* " 2008,Humana Press,.
REFERENCE BOOKS	
1	Sanjeeb K. Sahoo, "Nanotechnology in Health Care", 2012,Jenny Stanford Publishing, , ISBN 9789814267212
2	Zeynep Altintas, " Biosensors and Nanotechnology: Applications in Health Care" 2017, Kindle Edition, Wiley,
E BOOKS	
1	Mukesh Yadav, Punuri Babu, Jae Song, Arun Kharat, " Nanotechnology and Human Health" 2022, ISBN: 9780323907514
2	Harry F. Tibbals, "Medical Nanotechnology and Nanomedicine" by series Perspectives in Nanotechnology, CRC press, 2017
MOOC	
1	https://onlinecourses.nptel.ac.in/noc23_ge21/preview
2	https://www.futurelearn.com/courses/nanotechnology-health

COURSE TITLE	**ARTIFICIAL INTELLIGENCE IN NANOTECHNOLOGY**			**CREDITS**	**3**
COURSE CODE	**ANO02505**	**COURSE CATEGORY**	**DE**	**L-T-P-S**	**2-1-0-0**

Version	1.0	Approval Details		LEARNING LEVEL	BTL3
ASSESSMENT SCHEME					
First Periodical Assessment	**Second Periodical Assessment**	**Seminar/ Assignments/ Project**	**Surprise Test / Quiz**	**Attendance**	**ESE**
15%	**15%**	**10%**	**5%**	**5%**	**50%**
Course Description	This course introduces Artificial Intelligence (AI) and its applications in Nanotechnology to develop functional materials and devices. It offers an integrated theoretical and practical training for engineering students to realize the importance of AI in the design and development of Nanomaterials and devices. It offers unique opportunity to understand the correlation between AI and emerging device technologies to solve major technological issues**.**				
Course Objectives	1. To introduce the applications of AI in various other technologies such as sensors, energy harvesting and biomedical devices. 2. To learn and apply the concepts of AI in Nanotechnology. 3. To apply AI based techniques to study stability, performance and reliability of Nanomaterials and devices. 4. To expose the scope of AI to students in the field of emerging device technologies.				
Course Outcomes	Upon completion of this course, the students will be able to 1. Apply the knowledge of AI into Nanomaterials to understand physical, chemical and mechanical properties. 2. Understand the concepts of AI and its applications in Nanotechnology. 3. Interpret the data from nanodevices using AI based techniques. 4. Monitor the failure mechanisms in Nanodevices using AI 5. Categorize the nanomaterials and devices in terms of performance and stability using AI				
Prerequisites: Knowledge in Physics and Mathematics at higher secondary level					

CO, PO AND PSO MAPPING

CO	PO-1	PO-2	PO-3	PO-4	PO-5	PSO-1	PSO-2	PSO-3
CO1	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**-**
CO2	**3**	**3**	**-**	2	**3**	**-**	**-**	**-**
CO3	**3**	**3**	**-**	**-**	**1**	**-**	**-**	**-**
CO4	**3**	**3**	**-**	**2**	**-**	**-**	**-**	**-**
CO5	**3**	**3**	**-**	**-**	**3**	**-**	**-**	**-**
1: Weakly related, 2: Moderately related and 3: Strongly related								

MODULE 1: ARTIFICIAL INTELLIGENCE, MACHINE LEARNING AND DEEP LEARNING	(12)
AI: Introduction-basics of AI-Types of AI-What is Machine Learning-What is Deep Learning-Physics of Nano-Issues in Nano-AI and Nano-The Current Scenario-New Challenges-Why AI in Nano-Significance of dimensions in applications-Role of AI in Nano-Applying the concepts of AI in Nanomaterials and devices-Future scope	**CO1 BTL 1 & 2**
MODULE 2: AI ASSISTED NANO SENSOR TECHNOLOGY	**(12)**
Introduction to sensor technology-Current Status-Materials-Flexible Sensors-Fabrication Methodologies-AI for Sensor Technology-Roles of AI in Sensors-Advantages-New opportunities-AI in Biosensors-AI in Pressure Sensors-AI assisted gas sensors-Motion sensors based on AI-Electrochemical sensors using AI technology-Future scope	**CO2 BTL 2 & 3**
MODULE 3: AI FOR BIOMEDICAL DEVICES	**(12)**
AI driven smart healthcare-AI based signal processing in biomedical devices-wearable biomedical devices and AI techniques-AI facilitated 3D-printed biomedical devices-THz healthcare technology and AI-Smart diabetic management using AI technology-future perspectives of nanomedicine and AI	**CO3 BTL 2 & 3**
MODULE 4: AI FOR NANOPHOTOVOLTAIC DEVICES	**(12)**
AI to predict the solar irradiance- AI to achieve maximum power point in photovoltaic device-Interfacial charge transport processes in photovoltaic devices through AI techniques-AI based loss analysis- AI assisted device modeling-AI in optical and electrical processes-Future scope	**CO4 BTL 2 & 3**
MODULE 5: AI BASED NANOGENERATORS AND ENERGY HARVESTING	**(12)**
Nanogenerators-Piezo electric - Triboelectric-AI for nanogenerators-Assess materials for nanogenerators via AI techniques-AI for vibrational energy harvesting-AI for data processing in energy harvesting system-AI techniques in solar energy harvesting-AI driven RF-energy harvesting	**CO5 BTL3**

TEXT BOOKS	
1	Janet Finlay and Alan Dix, An Introduction to Artificial Intelligence, CRC Press, 2020.
2	Zoltán Somogyi, The Application of Artificial Intelligence Step-by-Step Guide from Beginner to Expert, Springer International Publishing, 2021.
REFERENCE BOOKS	
1.	Cherry Bhargava, Pradeep Kumar Sharma, Artificial Intelligence Fundamentals and Applications, CRC Press, 2021
2.	Yuebing Zheng, Zilong Wu, Intelligent Nanotechnology Merging Nanoscience and Artificial Intelligence, Elsevier Science, 2022.
3.	Research articles in related areas to the modules 1-5