M.Tech.

IN

NANOTECHNOLOGY

CURRICULUM AND SYLLABI

(Applicable from 2023 admission onwards)

School of Materials Science and Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M.Tech.in Nanotechnology

PEO1	Graduates from diverse academic backgrounds in engineering and science shall demonstrate creativity, critical thinking and research aptitude on the fundamental and applied topics in nano science and technology.
PEO2	Graduates shall do innovative research in the interdisciplinary areas of nanotechnology.
PEO3	Graduates shall contribute by providing engineering solutions through sustained academic and professional activities.

Programme Outcomes (POs) & Programme Specific Outcomes (PSOs) of M.Tech. in Nanotechnology

PO1	Ability to independently carry out research and innovation to solve practical problems.
PO2	Ability to express and communicate the acquired technical knowledge effectively.
PO3	Ability to demonstrate a degree of mastery in the learned subjects.
PSO 1	Ability to demonstrate a sound technical knowledge of basic scientific and engineering principles in the field of Materials Science and Nanotechnology.
PSO 2	Ability to do innovations in various areas of materials science, nano science and technology and contribute to the industries, R&D and academics.

CURRICULUM

Total credits for completing M.Tech. in Nanotechnology is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech. programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	23
2.	Program Electives (PE)	15
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MT6101E	Experimental Techniques for Materials	3	0	2	8	4	PC
2.	MT6102E	Thermodynamics of Materials	3	0	0	6	3	PC
3.	MT6103E	Nanosized Structures	3	0	0	6	3	PC
4.		Programme Elective-1	3	0	0	6	3	PE
5.		Programme Elective-2	3	0	0	6	3	PE
6.	MT6191E	Nanoscience and Technology Lab-I	0	0	3	3	2	PC
7.	MT6192E	Seminar	0	0	3	3	2	PC
8.		Institute Elective	2	0	0	4	2	IE
		Total					**22**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MT6111E	Spectroscopy for Nanomaterials	3	0	0	6	3	PC
2.	MT6112E	Microscale and Nanoscale Heat Transfer	3	0	0	6	3	PC
3.		Programme Elective-3	3	0	0	6	3	PE
4.		Programme Elective-4	3	0	0	6	3	PE
5.		Programme Elective-5	3	0	0	6	3	PE
6.	MT6193E	Nanoscience and Technology Lab-II	0	0	6	6	3	PC
7.	MT6194E	Project Phase I	0	0	0	6	2	PC
		Total					**20**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MT7195E	Project Phase II (To be completed during Summer)	0	0	0	30	3	PC
2.	MT7196E	Project Phase III	0	0	0	35	15	PC
		Total					**18**	**--**

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MT7197E	Project Phase IV	0	0	0	35	15	PC
		Total					**15**	**--**

List of Electives *

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MT6121E	Nano Materials for Energy and Environment	3	0	0	6	3
2.	MT6122E	Computational Nanotechnology	3	0	0	6	3
3.	MT6123E	Carbon Nanomaterials	3	0	0	6	3
4.	MT6124E	Combustion and Nanoparticle Fuel-Additives	3	0	0	6	3
5.	MT6125E	Polymer Technology	3	0	0	6	3
6.	MT6126E	Chemistry of Materials	3	0	0	6	3

7.	MT6127E	Nanofabrication	2	0	2	6	3
8.	MT6128E	Elements of X-Ray Diffraction	3	0	0	6	3
9.	MT6129E	Surface Science with Nanomaterials	3	0	0	6	3
10.	MT6130E	Micro Electro Mechanical Systems and applications	3	0	0	6	3
11.	MT6131E	Materials for Thermal Management and Energy Conversion	3	0	0	6	3
12	MT6132E	Applied Transmission Electron Microscopy	3	0	0	6	3

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	IE6001E	Entrepreneurship Development	2	0	0	4	2
2.	ZZ6002E	Research Methodology	2	0	0	4	2
3.	MS6174E	Technical Communication and Writing	2	0	0	4	2

For electives, students may credit any M. Tech. level course offered in the Institute with the approval from the Programme Coordinator and Head of the Department. The consent of the Course Faculty also needs to be obtained.

MT6101E EXPERIMENTAL TECHNIQUES FOR MATERIALS

Pre-requisites: NIL

L	T	P	O	C
3	0	2	8	4

Total Sessions: 39L + 26P

Course Outcomes:

CO1: Examine various techniques for particle size measurement.
CO2: Distinguish the microscopic measurement techniques for the material characterization.
CO3: Apply different experimental techniques for the surface analysis of the materials
CO4: Analyse the underlying concepts and instruments for thermal analysis and film thickness measurement.

Design of Experiments - Best guess approach, One factor at time approach, Factorial approach. Elementary ideas of blocking, randomization, replication. Errors, Uncertainty analysis. Particle size distribution – Dynamic image analysis (DIA), Static laser light scattering (SLS), Dynamic light scattering (DLS), Attenuation spectroscopy, Zeta potential, Surface streaming potential. Optical microscope - Basic principles and components, Resolution and Magnification, Different modes of operation (Bright field illumination, Oblique illumination, Dark field illumination), Stereomicroscopy,

Scanning Electron Microscopy - instrumentation and application, different imaging modes sample preparation techniques - Transmission electron microscopy- different modes of operation, contrast mechanisms, HRTEM, SAED, EELS, Electron back scattering (EBSD) - X-ray micro analysis (EDS, WDS).

Surface Analysis: Scanning probe microscopy, tapping mode, contact mode, MFM, EFM, I-AFM, DC-AFM, PFM, FMM, LFM, SCM, SThM, SKM, F-d spectroscopy, Nanoindentation, Nano scratching, scanning tunnelling microscopy, Scanning near field microscopy (SNOM), X-ray photoelectron spectroscopy, XRD.
Surface area - Gas Sorption Technique - Brunauer–Emmett–Teller (BET) theory, Mercury Intrusion Porosimetry (MIP). Surface roughness: Direct measurement methods, Non-contact methods.

Temperature measurement**:** Infrared thermography, Thermo reflectance thermography, Liquid crystal thermography. Interferometry. Thermal Analysis**:** Differential Scanning Calorimeter (DSC), Differential Thermal Analyzer (DTA), Thermogravimetric Analysis (TGA) - Dynamic mechanical analysis (DMA)-Temperature programme reduction (TPR). Coating thickness measurement: Ultrasonic measurement, Magnetic Induction method, Eddy current method, Ultrasonic thickness gauges.

References:
1. Robert K., Ian H., Mark G., Nanoscale Science and Technology, john Wiley & sons Ltd.,2007.
2. Weilie Zhou and Zhong Lin Wang, Scanning Microscopy for Nanotechnology, Springer 2007.
3. David B. Williams, C. Barry Carter, Transmission Electron Microscopy, Springer 2009.
4. Nan Yaho and Zhong, Hand book of Microscopy for Nanotechnology, Kluwer Academic press, Boston, 2005.
5. K.S. Birdi, Scanning Probe Microscopy, CRC Press, 2003.
6. Ernest O. Doeblin, Measurement Systems: Application and Design, McGraw Hill (Int. Edition) 1990.
7. Micheal E. Brown, Introduction to Thermal Analysis, Techniques and applications, Kluwer Academic Publishers 2001.
8. Peter Eaton, Paul West, Atomic Force Microscopy, Oxford University Press, 2010.

MT6102E THERMODYNAMICS OF NANOMATERIALS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Examine thermodynamics and physical properties of nanomaterials and systems.
CO2: Distinguish thermodynamic functions and laws of thermodynamics applicable to nanoscale systems
CO3: Analyze thermodynamic equilibrium and phase stability
CO4: Assess the application of thermodynamics in nanoscale systems and nanomaterial development.

First Law of Thermodynamics, heat, work, heat capacity, enthalpy and internal energy, Second Law of Thermodynamics – Entropy and Criterion for Equilibrium – Statistical interpretation of entropy – Boltzmann equation.

Auxiliary Functions – Thermodynamic Relations – Maxwell's Equations – Gibbs - Helmholtz Equation – Examples – Heat capacity, enthalpy, entropy and the third law of Thermodynamics- First, second, and third laws of thermodynamics as applied to nanoscale systems.

Phase equilibrium in a one – component system – Composition and Phase diagrams of binary Systems – Criteria for Phase stability – Thermodynamics and kinetics of phase transformations- Homogeneous nucleation- Heterogeneous nucleation.

Physical phenomena of small systems - nano-crystals, macromolecules, thermodynamics and physical properties of long chain molecules and molecular structures.

References:

1. David V. Ragone, Thermodynamics of Materials, Volume I, J. W. Wiley 1995.
2. Robert T. De Hoff,Thermodynamics in Materials Science, McGraw-Hill, 2006
3. Y.K. Rao, Stoichiometry and Thermodynamic Computations in Metallurgical Processes, Cambridge University Press, 1985.
4. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2007.
5. Daniel V. Schroeder: An Introduction to Thermal Physics, Addison-Wesley, 2021

MT6103E NANOSIZED STRUCTURES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse different nanosystems and their properties.
CO2: Appraise the concepts and principles of various methods for stabilization of the functional nanomaterials.
CO3: Assess the synthesis and fabrication of emerging nanomaterials and hybrid materials.
CO4: Apply the nanoparticles in advanced applications of nanomaterials.

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Introduction to nanomaterials, quantum confinement, properties and applications, band gap engineering and property tuning, surface science for nanomaterials, surface energy, stabilization mechanisms, electrostatic - Nernst Equation, electric double layer, zeta potential, Interaction between nanoparticles - DLVO Theory, steric stabilization and electrosteric stabilization, nucleation and growth of nuclei, critical radius, homogenous and heterogeneous nucleation.

Bottom-up approaches for nanostructure fabrication: Metal nanocrystals by reduction, Solvothermal, Photochemical, Template based and Electrochemical synthesis, Nanocrystals of semiconductors and oxides, sol-gel, micelles and microemulsions, top-down approaches for nanostructure fabrication.Quantum clusters of metals, properties, Quantum clusters as catalysts

Anisotropic nanomaterials, properties and applications, One dimensional nanostructures, evaporation condensation growth, Vapor –Liquid-Solid (VLS) growth, electrospinning, Two dimensional nanostructures, thin films, single and multilayered material structure, molecular beam epitaxy, chemical vapour deposition, atomic layer deposition, molecular self-assembly phenomena, Langmuir-Blodgett films and self-assembled monolayers, emerging hybrid materials, nanoporous materials.

Nanomaterials for advanced technology- Photonic crystals, molecular electronics and nanoelectronics, Single electron transistors, Nanoparticle-biomaterial hybrid systems for bioelectronic devices, nanostructures in biodiagnostics, tissue engineering and drug delivery, catalysis, size and shape dependent catalysis, nanotoxicology.

References:

1. G. Cao and Y.Wang, Nanostructures and Nanomaterials, 2nd Ed., Imperial College Press, 2011.
2. R. Kelsall, I.Hamley and M. Geoghegan, Nanoscale Science and Technology, Wiley, 2005.
3. K. J Klabunde, R. M. Richards, Nanoscale Materials in Chemistry, 2nd Ed., Wiley, 2009.
4. T. Pradeep, A text book of Nano Science and Technology, Tata McGraw-Hill Education, 2012.
5. G. Schmidt, Nanoparticles: from Theory to applications, Wiley-VCH, 2011.

MT6191E NANOSCIENCE AND TECHNOLOGY LAB-I

Pre-requisites: NIL

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

CO1: Appraise the application of nanofluids in various fields.
CO2: Adapt experimental methodologies suitable for the characterization of nanofluids.
CO3: Choose nanomaterials for various applications.
CO4: Interpret the experimental results and prepare technical report.

Syllabus / List of Experiments:

1. Preparation of nanofluids
2. Measurement of stability of nanofluids
3. Performance evaluation of nano-fuel additives
4. Tribological studies of nano-lubricants
5. Thermal conductivity measurement of nanofluids
6. Nanomaterials for enhancing performance of heat exchangers
7. Quenching studies in nanofluids
8. Determination of viscosity of nanofluids
9. Evaporation studies of nanofluids
10. Absorption/Adsorption of gases in nanomaterials
11. Optical properties of nanomaterials
12. Nanomaterials for solar thermal applications
13. Thermal characterization of materials using interferometry

References:

1. Sarit K. Das, Stephen U. Choi, Wenhua Yu, T. Pradeep, Nanofluids: Science and Technology, Wiley, 2008.
2. Vincenzo Bianco, Oronzio Manca, Sergio Nardini, Kambiz Vafai, Heat Transfer Enhancement with Nanofluids, CRC Press, 2017.
3. Amy S. Fleischer, Thermal Energy Storage Using Phase Change Materials: Fundamentals and Applications, Springer, 2015.
4. Mohsen Sheikholeslami, Davood Domairry Ganji, Applications of Nanofluid for Heat Transfer Enhancement, Elsevier, 2017.
5. S M Sohel Murshed, Carlos Nieto de Castro, Nanofluids: Synthesis, Properties and Applications, Nova Science Publishers, 2014.

MT6192E SEMINAR

Pre-requisites: NIL

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

CO1: Develop presentation skill and defend in front of an expert panel.
CO2: Create awareness in recent development in the field of nanotechnology
CO3: Interpret scientific literature and write technical report

Each student shall prepare a paper on any topic of interest in the field of specialization – Nanotechnology. He/she shall get the paper approved by the programme Coordinator/ Faculty in-charge and present it in the class in the presence of Faculty in-charge of seminar class. Every student shall participate in the seminar. Grade will be awarded on the basis of the student’s paper, presentation and his/her participation in the seminar.

MT6111E SPECTROSCOPY FOR NANOMATERIALS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply the concepts and principles of spectroscopic methods for the characterization of Nanomaterials.
CO2: Interpret the analytical information for the comprehensive characterization of nanomaterials.
CO3: Assess the suitable technique for the apt evaluation of nanomaterials.
CO4: Appraise the electrochemical methods to comprehend the nanomaterial.

Surface analytical techniques, Surface sensitivity, Basic elements of practical spectroscopy, Infrared spectroscopy (IR), Functional groups, Attenuated total internal reflection IR, Diffuse reflectance and specular reflectance, AFM-IR, Raman Spectroscopy, resonance Raman, surface enhanced Raman and Tip enhanced Raman spectroscopy, Confocal Raman microscopy, analysis of carbon nanomaterials by Raman spectroscopy, Analysis of nanomaterials using IR, Raman spectroscopy.

UV-Visible absorption spectroscopy, Principle and application in nanomaterials, Metal nanoparticles and semiconductor nanoparticles, Diffuse reflectance, Calculation of band gaps, Fluorescence spectroscopy, Photoluminescence of nanomaterials, Photoelectron spectroscopy, Ultraviolet photoelectron spectroscopy and X-ray photoelectron spectroscopy, detailed analysis of spectra, X-ray Fluorescence, Auger electron spectroscopy, Electron energy loss spectroscopy.

Mass spectrometry techniques -Basics and application in nanomaterials, Tandem Mass, Matrix Assisted Laser Desorption/Ionisation, Secondary ion mass spectrometry, Electron spray ionization, Analysis of quantum clusters using mass spectrometry.

An overview of electrochemistry, Electrochemistry in materials science, Processes at electrodes, Electrochemical instrumentation and techniques, Cyclic voltammetry, Differential pulse voltammetry, Impedance spectroscopy, Electro chemiluminescence, spectroelectrochemistry, scanning electrochemical microscopy, Electrochromic and photoelectrochromic aspects of nanostructured metal oxide films.

References:

1. J. O'Connor, B. Sexton, R. Smart, Surface Analysis Methods in Materials Science, Springer, 2003.
2. Helmut Gunzler and Alex Williams, Handbook of Analytical Techniques, Wiley-VCH, 2002.
3. C. Banwell and E. Mccash, Fundamentals of Molecular Spectroscopy, Mc Graw Hill, 2001.
4. Allen J. Bard, Larry R. Faulkner, Electrochemical Methods: Fundamentals and Applications, Wiley-VCH, 2001.
5. D.P. Woodruff, Modern Techniques of Surface Science, Cambridge University Press, 2016.

MT6112E MICROSCALE AND NANOSCALE HEAT TRANSFER

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Contrast microscale and nanoscale heat transfer analysis and conventional heat transfer.
CO2: Develop fundamentals, measurements and applications of microscale heat conduction.
CO3: Examine microscale convective heat transfer, its measurement and applications.
CO4: Discuss fundamentals of nanoscale heat transfer and its important applications.

Introduction to microscale heat transfer - Observations on deviations from conventional theory – experimental and theoretical findings – Overview of studies and comparison of results – Introductory ideas about single phase, multiphase and gas flow in small channels – Contradictory observations and viewpoints in microchannel heat transfer-Applications of microscale heat transfer – basic ideas on micro heat exchangers and microscale heat sinks – applications.

Conduction in integrated circuits and their constituent films – current trends and future challenges –Microscale thermometry techniques – electrical and optical methods – thermo-reflectance thermometry – Thermal properties of amorphous dielectric films – Thermal characterization and heat transport in dielectric films – Heat conduction in crystalline silicon films – Phonon dispersion - heat conduction in semi-conductors at high temperatures

Fundamentals of convective heat transfer in microtubes and channels – Thermodynamic concepts, general laws and particular laws - Governing equations and size effects. Single phase forced convection in microchannels – Flow structure – entrance length – experimental observations on flow and heat transfer characteristics – Theoretical investigations – Forced convection in mixtures - Gas flow in microchannels. Boiling and two- phase flow heat transfer in small channels – Boiling curve and critical heat flux - flow patterns – Applications of microchannel heat transfer – micro heat pipes and micro heat spreaders

Fundamentals of heat transport in the nanoscale – characteristic lengths and heat transfer regimes –Nanoscale heat transfer phenomena.
Applications of nanoscale heat transfer in microelectronics, energy, nanomaterial synthesis, nanofabrication – Nanowires and carbon nanotubes – Analytical methods – Molecular dynamics simulation – Challenges and Future applications

References:

1. C B Sobhan, G P Peterson, Microscale and Nanoscale Heat Transfer-Fundamentals and Engineering Applications, Taylor and Francis/CRC, 2019.
2. Ju, Y.S., and Goodson, K., Microscale Heat Conduction in Integrated Circuits and their Constituent Films, Kluwer Academic Publishers, Boston, 2012.
3. Chen, G., Nanoscale Energy Transport and Conversion, Oxford University Press, 2005.
4. Mohamed Gad – el – Hak (ed.), The MEMS Handbook, Second Edition, CRC Press, 2006.

MT6193E NANOSCIENCE AND TECHNOLOGY LAB-II

Pre-requisites: NIL

L	T	P	O	C
0	0	6	6	3

Course Outcomes:

CO1: Assess various methods for the synthesis of nano materials
CO2: Propose suitable experimental techniques for the characterization of nano materials
CO3: Interpret the experimental results and prepare technical report

Syllabus / List of Experiments:

1. Synthesis of cerium zirconium oxide nanoparticle by co-precipitation method
2. Synthesis of ceria nano fibres by Solvo thermal method
3. Electrochemical deposition of palladium over graphite electrode coated with CNT
4. Synthesis of silica nanoparticles using Stober method
5. Development of a silica sol gel coating on a mica sheet
6. Synthesis of Iron oxide nanoparticles using co-precipitation method
7. Synthesis of molybdenum disulfide nanoparticles
8. Synthesis of titania nano fibers by hydrothermal method
9. Synthesis of gold nano particles using chemical reduction method
10. Fabrication and wettability characterization of nanostructured soft polymer surfaces

References:

1. Pradeep, T. A textbook of nanoscience and nanotechnology. Tata McGraw-Hill Education, 2017.
2. Chandran PR, Naseer M, Udupa N, Sandhyarani N. Size controlled synthesis of biocompatible gold nanoparticles and their activity in the oxidation of NADH, Nanotechnology, 8;23(1):015602, 2011.
3. Ibrahim IA, Zikry AA, Sharaf MA. Preparation of spherical silica nanoparticles: Stober Silica. J. Am. Sci.6(11), 985-9, 2010.
4. Chen X, Mao SS. Titanium dioxide nanomaterials: synthesis, properties, modifications, and applications. Chemical reviews, Jul 11;107(7):2891-959, 2007.

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MT6194E PROJECT PHASE I

Pre-requisites: NIL

L	T	P	O	C
0	0	0	6	2

Project Phase I is normally an initiation into the project.

Course Outcomes:

CO1: Understand the process of reviewing and recording the literature.
CO2: Analyze the literature and identify a project problem.
CO3: Apply the learning to define the objective and work plan for the project.
CO4: Develop and improve skills on focused research learning, presentation and communication.

Each student shall identify a topic of interest related to the core/elective courses undergone in the first semester of the M. Tech. programme. He/she shall get the topic approved by the project guide in the concerned area of specialization. The student is expected to conduct a literature survey. A mid semester evaluation shall be done by the guide. At the end of the semester the student shall present the project problem and the related literature in the presence of the duly constituted evaluation committee. Grade will be awarded on the basis of the student's work and presentation.

MT7195E PROJECT PHASE II

Pre-requisites: NIL

L	T	P	O	C
0	0	0	30	3

Course Outcomes:

CO1: Develop a systematic procedure to solve the identified research/industrial problem (This primarily pertains to the objective of Phase 2)
CO2: Analyse and Identify a suitable research methodology for solving the problem identified.
CO3: Apply the methods/tools learned to develop new methodologies and solve the problem.
CO4: Apply the techniques of academic writing, critical analysis for consolidating the results to make a report and defend the thesis.
CO5: Create valuable academic/research outcomes such as high impact publications and intellectual property rights.

Project Phase II can be an extension of Phase I or internship outside during the summer semester break.
Students shall continue to work on the problem identified in the project phase I or undergo internship outside. Students shall identify the methodology, apply for a preliminary work. The work should be suitable for communicating to a conference. The student shall submit a report. All the projects will be evaluated by a duly constituted committee.

MT7196E PROJECT PHASE III

Pre-requisites: NIL

L	T	P	O	C
0	0	0	35	15

Course Outcomes:

CO1: Develop a systematic procedure to solve the identified research/industrial problem (This primarily pertains to the objective of Phase 2)
CO2: Analyse and Identify a suitable research methodology for solving the problem identified.
CO3: Apply the methods/tools learned to develop new methodologies and solve the problem.
CO4: Apply the techniques of academic writing, critical analysis for consolidating the results to make a report and defend the thesis.
CO5: Create valuable academic/research outcomes such as high impact publications and intellectual property rights.

The project work can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project work in an industry or in other organizations have to fulfil the requirements as specified in the "Ordinances and Regulations for M. Tech." The student is expected to complete the pilot study, redefine the project based on pilot study, decide on the appropriate research design, develop methodology, generate data/collect data, and obtain preliminary results in the third semester. There shall be evaluations of the project work during and at the end of the third semester by a committee constituted by the department.

Students who wish to do internship outside the Institute as part of project phase III will be permitted based on the department policies from time to time. The evaluation of the internship will be based on appropriate rubrics arrived by the evaluation committee.

MT7197E PROJECT PHASE IV

Pre-requisites: NIL

L	T	P	O	C
0	0	0	35	15

Course Outcomes:

CO1: Develop a systematic procedure to solve the identified research/industrial problem (This primarily pertains to the objective of Phase 2)
CO2: Analyse and Identify a suitable research methodology for solving the problem identified.
CO3: Apply the methods/tools learned to develop new methodologies and solve the problem.
CO4: Apply the techniques of academic writing, critical analysis for consolidating the results to make a report and defend the thesis.
CO5: Create valuable academic/research outcomes such as high impact publications and intellectual property rights.

The project work will be extended to the end of the fourth semester. There shall be evaluations of the project work by a committee constituted by the department during the fourth semester. The student shall submit the thesis based on the recommendation of the departmental evaluation committee. There shall be viva-voce examination conducted by an evaluationcommittee with an external examiner.

Students who wish to do internship outside the Institute as part of project phase IV will be permitted based on the department policies from time to time. The evaluation of the internship will be based on appropriate rubrics arrived by the evaluation committee.

List of Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	MT6121E	Nano Materials for Energy and Environment	3	0	0	6	3
2.	MT6122E	Computational Nanotechnology	3	0	0	6	3
3.	MT6123E	Carbon Nanomaterials	3	0	0	6	3
4.	MT6124E	Combustion and Nanoparticle Fuel-Additives	3	0	0	6	3
5.	MT6125E	Polymer Technology	3	0	0	6	3
6.	MT6126E	Chemistry of Materials	3	0	0	6	3
7.	MT6127E	Nanofabrication	2	0	2	6	3
8.	MT6128E	Elements of X-Ray Diffraction	3	0	0	6	3
9.	MT6129E	Surface Science with Nanomaterials	3	0	0	6	3
10.	MT6130E	Micro Electro Mechanical Systems and applications	3	0	0	6	3
11.	MT6131E	Materials for Thermal Management and Energy Conversion	3	0	0	6	3
12	MT6132E	Applied Transmission Electron Microscopy	3	0	0	6	3

MT6121E NANOMATERIALS FOR ENERGY AND ENVIRONMENT

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply the concepts and principles of conversion and storage of renewable energy sources.
CO2: Evaluate the efficiency of nanocatalysts for electrochemical energy generation and storage.
CO3: Design the suitable nanomaterials for environmental remediation.
CO4: Analyze the toxicity of nanomaterials.

Energy and Environment, sustainable energy production based on renewable energy sources, Sustainability: Water, Energy, Nanomaterials used in energy and environmental applications and their properties**,** Solar energy, solar cells, dye sensitized solar cell, QDSSC, organic solar cells, perovskite solar cells, Hydrogen energy, hydrogen production by water splitting, hydrogen storage.

Electrochemical energy conversion and storage systems, Fuel cells, Types of fuel cells, thermodynamics of fuel cells, electrocatalysts for anode reactions, catalysts for oxygen reduction reactions, Batteries, Li-ion battery, Na-ion battery, General properties of electrochemical capacitors, Supercapacitor, Electrical double layer capacitor, pseudocapacitor, Li-ion based hybrid supercapacitors, Applications of electrochemical capacitors.

Green nanotechnology and its principles, Nanomaterials for environmental Remediation, Photocatalysis, Water purification using nanomaterials, desalination of water, Solid waste removal, Porous materials to store clear energy gases, Metal organic frame works (MOFs), Storage of carbon dioxide, methane and hydrogen in MOFs.

Potential impacts of nanomaterials on organisms and ecosystems, Nanotoxicology**,** Introduction to nanomaterial toxicity, environmental and health impacts, Biomagnification, Nanoparticles exposure assessment, toxicity of inhaled nanomaterials, Basics of toxicity studies, Cytotoxicity induced by nanomaterials, ethical, legal, and societal implications of nanotechnology.

References:

1. Jingbio louise Liu, Sajid Bashir, Advanced Nanomaterials and their applications in Renewable energy, Elsevier, 2015.
2. Tetsuo Soga, Nanostructured Materials for Solar Energy Conversion, Elsevier, 2006.
3. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kluwer Academic Publishers, Dordrecht, Netherlands, 2004.
4. J. Larmine and A. Dicks, Fuel Cell System Explained, John Wiley, New York, 2018.
5. Francois B´eguin and El˙zbieta Frackowiak, Supercapacitors, Wiley-VCH, 2013.
6. Challa S.S.R. Kumar, Nanomaterials: toxicity, health and environmental issues, Wiley-VCH, 2006.

MT6122E COMPUTATIONAL NANOTECHNOLOGY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions:39

Course Outcomes:

CO1: Develop computational simulation methodologies and discuss their applications.
CO2: Assess the application statistical mechanics and theorems involved.
CO3: Analyze physical problems with the help of atomistic simulation techniques.
CO2: Analyze problems using mesoscopic simulation techniques.

Introduction- Computational simulation, need for discrete computation. Classical Mechanics: Mechanics of Particles, D' Alembert's principle and Lagrange's equation, variational principles, Hamilton's principle, conservation theorems and symmetry properties, central force problems, virial theorem.

Statistical Mechanics: Review of probability and statistics, quantum states of a system, equations of state, canonical and microcanonical ensemble, partition function, energy levels for molecules, equipartition theorem, minimizing the free energy, partition function for identical particles, Maxwell distribution of molecular speeds.

Atomistic Simulation Techniques:
Molecular Dynamics (MD): Introduction, inter-atomic potential function, Lennard-Jones potential, MD simulation – equilibration and property evaluation, various types of potential functions, computational aspects, introduction to advanced topics. Monte Carlo (MC) Method: Introduction, Metropolis algorithm, advanced algorithms for Monte Carlo simulations, comparison with Molecular Dynamics.

Mesoscopic Simulation Techniques:
Lattice Boltzmann Method (LBM): Boltzmann equation, derivation of the hydrodynamic equation from Boltzmann equation, Lattice Boltzmann equation and LBM, applications of LBM. Dissipative Particle Dynamics (DPD): Fundamentals of DPD simulations, time step size and noise, repulsion parameter, approximate expressions for transport coefficients. Introduction to Multiscale methods and applications.

References:

1. Bird, G.A., Molecular Gas Dynamics and the Direct Simulation of Gas Flows, Oxford Science Publications, 2003.
2. Goldstein, H., Poole, C., and Safko, J., Classical Mechanics, 3rd Edn., Pearson Education, 2011.
3. Bowley, R., and Sanches, M., Introductory Statistical Mechanics, 2nd Edn., Oxford Science Publications, 2007.
4. Ercolessi, F., A Molecular Dynamics Primer, Notes of Spring College in Computational Physics, ICTP, Trieste,1997.

MT6123E CARBON NANOMATERIALS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Appraise the concepts of carbon-based nanostructures.
CO2: Analyse the synthesis and characterization techniques of carbon-based nanostructures.
CO3: Appraise the applications and challenges of carbon nanostructures.
CO4: Develop skill to design devices based on carbon nanoscience.

Different carbon-based nanostructures, Historical developments: Fullerenes, Graphene, Carbon nanotubes, carbon dots, pyrolyzed nanocarbons, hard carbons and its derivatives, Common synthesis technique for carbon nanostructures: arc evaporation, laser ablation and chemical vapor deposition, purification by dry and wet method, Pyrolysis- structural evolution during pyrolysis, glassy carbon, different structural models. Techniques for alignment of CNTs: horizontal alignment and vertical alignment, organization on surfaces: organized assembly, field and flow directed growth, surface directed growth(epitaxy), patterned growth on surfaces. Other synthesis methods. Large area graphene synthesis. Defect free transfer methods for large area graphene.

Mechanical properties of graphene, carbon nanotubes, pyrolyzed nanocarbons and other carbon nanomaterials, Thermal properties of graphene, carbon nanotubes, pyrolyzed nanocarbons and other carbon nanomaterials. Thermal stability, Thermal conductance, Influence of defects on thermal conductivity, Electronic and Optoelectronic properties of graphene, Carbon nanotubes and Pyrolyzed nanocarbons. Characterisation of carbon nanomaterials, Raman Spectroscopy, Electron microscopy, SPM, Photoluminescence spectroscopy, Defect engineering in carbon nanomaterials and its effect on properties. Doping and effect of doping on properties.

Carbon nanomaterials for MEMS and NEMS applications, Sensors and actuators based on carbon nanomaterials, Carbon nanomaterials for energy storage, graphene, CNT, reduced graphene oxide and its derivates as electrodes for batteries and supercapacitors, Hard carbon electrodes-structure, properties and microstructural engineering, Metal ion storage mechanism in carbon-based electrodes, Environmental and health effects of carbon nanomaterials, application of graphene, CNT, carbon dots and other carbon nanomaterials in biomedical application, nano carbon-based biosensors and implantable biosensors.

References:

1. Jorio, A., Dresselhaus, G., and Dresselhaus, M.S., Carbon Nanotubes – Advanced Topics in the Synthesis, Structure, Properties and Applications, Springer Verlag, New York, 2008.
2. Michael J. O'Connell, Carbon Nanotubes: Properties and Applications, CRC, 2006.
3. Jorio, A.; Dresselhaus, M. S.; Saito, R. & Dresselhaus, G. Raman spectroscopy in graphene related systems Wiley, 2011.
4. Krueger, A., Carbon materials and nanotechnology Carbon Materials and Nanotechnology, Wiley-VCH, 2010.

MT6124E COMBUSTION AND NANOPARTICLE FUEL-ADDITIVES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Appraise the thermodynamic aspects of combustion.
CO2: Analyze combustion kinetics in fuel burning systems.
CO3: Compare the combustion phenomena in SI and CI engines.
CO4: Assess the influence of nanoparticles in engine exhaust emission reduction.

Review of basic thermodynamics and gaseous mixtures, Combustion Thermodynamics, Stoichiometry, First and Second Laws of Thermodynamics applied to combustion, Composition products in equilibrium.

Fundamentals of combustion kinetics, General characteristics of combustion flame, detonation, deflagration, Factors affecting flame velocity and thickness, Quenching, Flammability, Flame stabilization, Laminar premixed flames, diffusion flames, Turbulent premixed flames.

Combustion in I.C. engines, A/F ratio requirements, Ignition temperature- Ignition delay, Normal combustion in SI engines, Knocking, Effect of variable on knocking tendency, Octane number, Normal combustion in CI Engines-Theories of detonation - Cetane number

Fuels for I.C. Engines, Properties of fuels, Measurement methods, Fuel additives, Nano catalysts, synthesis and characterization of Ceria based oxide nanoparticles, Oxygen storage capacity, Nano fluids, Diesel engine emissions, Effect of nano particles on fuel properties and emissions, Emission control devices.

References:

1. Stephen R Turns, An Introduction to Combustion, McGraw- Hill International Edition, 2011.
2. Kuo, K. K., Principles of Combustion, John Willey & Sons, 2005.
3. Mukunda, H. S., Understanding Combustion, Macmillan India Ltd., 2009.
4. Smith, M. L. and Stinson, K. W., Fuels and Combustion, McGraw-Hill, 1952.
5. Heywood, J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, 2017.
6. Fristrom. R. M. and Westenberg, A. A., Flame Structure, McGraw – Hill Book Co. New York, 1965.
7. Maleev, M. L., Internal Combustion Engines, McGraw-Hill, 1989.
8. Mathur, M. L. and Sharma, R. P., Internal Combustion Engines, Dhanpath Rai & Sons, 2005.
9. G. R. Pryling, Combustion Engineering, Revised Edn, Combustion Engg. Inc., New York 1967.
10. C. Eckbreth, Laser Diagnostics for Combustion Temperature and Species, Cambridge, Abacus Press, 1996.
11. Sajith V. and Shijo Thomas, “Internal Combustion Engines”, Oxford University Press, 2017.

MT6125E POLYMER TECHNOLOGY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply the concepts and principles of polymer technology.
CO2: Interpret the analytical information for the characterization of polymers.
CO3: Assess the suitable technique for the apt evaluation of polymers.
CO4: Perceive the viscoeleastic behavior of polymers.

Introduction to Polymers, Basic concepts, characteristic features, texture of polymers, molecular forces and chemical bonding, secondary bond forces, tacticity in polymers, stereo isomerism in polymers, basic determinants of polymer properties, polymer chain flexibility, factors affecting chain flexibility, glass transition temperature and crystalline melting points, variation and structure, molecular interpretation of glassy state of polymers.

Compounding and processing of polymers, Additives for compounding plastics, additives for compounding of rubbers, two roll mill, banbury mixer, pigments, processing aids, processing methods for the manufacture of products, blending and mastication, masterbatching, mixing and compounding, calendaring, extrusion and moulding. Different elastomer curing systems-efficient, semi efficient, conventional and sulphurless curemechanism of vulcanization, sulphur vulcanization, non-sulphur vulcanizing systems for olefin rubbers, batch vulcanization-autoclave, gas curing, oven curing, water curing, cold curing, continuous vulcanisation-high performance steam, hot air tunnel, molten salt bath, fluidized bed, continuous drum cure, microwave curing.

Testing of Rubbers. Importance of standards and standards organizations, processability and performance, testing of plastics and rubbers, material characterization tests such as hardness, tensile stress/strain, compression stress/strain, shear stress/strain, flexuaral stress/strain, tear tests, rebound resilience, friction, creep, fatique, melt flow index, capillary rheometer test, viscosity test, gel permeation chromatography, thermal analysis such as TGA, TMA, and DSC.

Introduction to polymer melt rheology, viscosity, types of fluid flow, time dependent fluids, time independent fluids, viscoelastic fluids, complex rheological fluids, Newtonian fluids, non-Newtonian fluids, Bingham plastics, psuedo plastics, rheopectic and thixotropic behaviour, rheological measurements-the capillary rheometer, cone and plate viscometer, melt flow index apparatus, elastic effects in polymer melt flow-die swell, elastic turbulance, melt fracture, sharkskin.

References:

1. Fred W. Billimeyer, Jr, Text Book of Polymer Science, third edition, Wiley Interscience Publication, 2007.
2. Joel R. Fried m., Polymer Science and Technology, Prentice- Hall, Inc. Englewood Cliffs, N. J., USA, 2014.
3. K. Bhowmic and H. C. Stephense, Hand book of Elastomers: New Developments and Technology, Marcel-Dekker Inc., New York, 1995.
4. D. R. Paul and S. Newman, Polymer Blends, Academic Press, New York, 1978.
5. M. J. Folkes, Short Fibre Reinforced Thermoplastics, John Wiley, New York, 1982.
6. Jacob Kline, Handbook of Biomedical Engineering, Academic press, NY, 1997.
7. Joseph D. bronzino, Donald R. Peterson, The Biomedical engineering Handbook, CRC press, London, 2015.

MT6126E CHEMISTRY OF MATERIALS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Recognize major classes of materials.
CO2: Describe relationships among structure & composition, physical & chemical properties.
CO3: Analyze the sustainability of materials processing and applications.
CO4: Apply appropriate laboratory techniques to process materials, determine their properties.

Structure of materials, crystal structures, introduction to lattices, bonding in solids, diffraction and reciprocal lattice, order and disorder in solids, electrical, optical and magnetic properties, unique bonding in nanoparticles and powders, novel properties of nanomaterials, classification of nanomaterials, interparticle interactions, superlattices.

Classes of materials, Semiconductors, metals and alloys, ceramics, polymers, dielectric and ferroelectric materials, magnetic materials, optical materials, super conductors, high Tc Materials, Perovskites, micro and mesoporous materials, nanoporous materials, aerogels, host-guest systems based on nanoporous crystals.

Physical chemistry of surfaces, interfaces, thin films, preparation, characterization and application, Langmuir-Blodgett films: growth techniques, self-assembled monolayers, nanocrystalline phases, preparation, nanocomposites, fullerenes, carbon nanotubes, graphene, carbon dots, effect of synthesis on the structure and properties of various materials.

Supramolecular chemistry, rotaxanes as ligands for molecular machines and metal-organic frameworks, synthetic nanotubes from calixarenes, molecular gels-nanostructured soft materials, periodic nanostructures based on metal-organic frameworks (MOFs).

References:

1. K. J. Klabunde, Richards Ryan, Nanoscale materials in chemistry, John-Wiley and sons, 2009.
2. A.R. West, Solid state chemistry and its applications, Wiley, 2014.
3. G. Gao, Nanostructures and nanomaterials, Imperial college press, 2006.
4. Jerry L.Attwood, Jonathan W. Steed, Organic nanostructures, Wiley-VCH, 2008.
5. F. Schuth, Kenneth, S.W. Sing, Jens Weitkamp, Handbook of porous solids, Wiley interscience, 2008.
6. F. Laeri, Ferdi Schuth, Ulrich Simon, Michael Wark, Host-guest-systems based on nanoporous crystals, Wiley interscience, 2003.

MT6127E NANOFABRICATION

Pre-requisites: NIL

L	T	P	O	C
2	0	1	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply the concepts and principles of different nanofabrication techniques.
CO2: Design and built nanofabricated surfaces for devices.
CO3: Assess the suitable technique for the deposition of nanomaterials.

Fabrication of Nanomaterials by Physical method: Nanofabrication by bottom up and top down approach, Inert gas condensation, ARC Discharge, RF Plasma. Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical and Physical vapor deposition method, Electro deposition, Nanogrinding, LPCVD.

Nanofabrication by photons and charged beams, Optical Lithography, Photoresist, Deep UV, Extreme UV and X ray Lithography, optical E-beam lithography mask making. Mask less optical lithography, contact proximity and projection lithography, Different etching techniques, reactive Ion Etching. ICPRIE, Thermal oxidation of silicon. Focused ion beam, Dual Beam and electron beam for nanolithography, Limitations of Lithography.

Nanofabrication by scanning probe, Nanoscratching and oxidation, soft lithography, nanoimprint lithography, lmmersion lithography, Deep pen lithography.

Nanofabrication by replication, Nanofabrication by self-assembly and scanning tunneling techniques, nanopatterning, Nanomanipulation. MEMS fabrication, Lab on Chip.

References:

1. Kazuaki Suzuki. Bruce W Smith. Microlithography: science and technology, CRC press 2020.
2. Mark J Jackson, Microfabrication and nanomanufacturing, CRC press Taylor & Francis Group, 2006.
3. John A. Rogers, Hong H Lee, Unconventional nanopatterning techniques and applications, Published by John Wiley & Sons, Inc., 2009.
4. Syed Rizvi, Handbook of Photomask Manufacturing Technology CRC Press Taylor & Francis Group, 2005.

MT6128E ELMENTS OF X-RAY DIFFRACTION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze XRD patterns of different crystalline phases
CO2: Interpret XRD data to deduce unit cell structure.
CO3: Determine the indices of diffracting planes in crystalline solids.
CO4: Predict residual stress and texture in crystalline solids.

Introduction- Electromagnetic radiation, continuous spectrum, characteristic spectrum, absorption, filters, Production of x-rays, Absorption of X-rays, Detection of x-rays. Diffraction - Bragg law, X-ray spectroscopy, Diffraction directions, Diffraction methods. Diffraction under nonideal conditions. Scattering by an electron, Scattering by an atom.

Lattices and crystal structures, Types of solid and order, Point lattices and unit cells, Crystal systems and Bravais lattices, Crystal structures, atoms per lattice points, Miller indices, Diffraction from crystalline materials. Scattering by a unit cell, Structure-factor calculations, Multiplicity factor, Lorentz factor, Absorption factor, Temperature factor. Intensities of powder pattern lines, Measurement of x-ray intensity.Structure factor.

Geometry of an X- Ray diffractometer, Components of an X-Ray diffractometer, X-Ray sources, Optics, detectors, X-ray safety, Crystal structure data, ICDD, JCPDS etc., Crystal structure determination Cubic, Hexogonal strucutures, Methods for indexing of XRD peaks, peak shift, residual stress.

Precise Parameter Measurements- Debye-Scherrer cameras, Method of least squares, Cohen's method, Calibration method, Phase diagram determination- General principles, Solid solutions, Determination of solvus curves- disappearing-phase method and parametric method, Ternary systems. Order – Disorder Transformations, Long-range order, Detection of superlattice lines, Short-range order and clustering.

References:

1. B.D.Cullity and S.R.Stock, Elements of X-Ray Diffraction Third edition, Prentice Hall, 2001.
2. Aaron.D. Krwitz, Introduction to Diffraction in Material Science and Engineering, Wiley-Interscience, 2001.
3. C. Suryanarayana and M.Grant Norton, X-Ray Diffraction - A Practical Approach, Springer, 2014.
4. K. Ramakanth Hebbar, Basics of X-Ray Diffraction and its Applications, I.K.International Publishing House, 2011.
5. Yoshio Waseda, Eiichiro Matsubara and Kozo Shinoda, X-Ray Diffraction Crystallography: Introduction, Examples and Solved Problems, Springer, 2011.

MT6129E SURFACE SCIENCE WITH NANOMATERIALS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Appraise the concepts of surfaces and interfaces.
CO2: Analyze the processes and characterization of surfaces.
CO3: Develop skill in constructing and designing smart surfaces.
CO4: Design and fabricate functional and smart materials.

The nature of surfaces and interfaces, Surface free energy, Molecular nature of Interfacial regions, surface activity and Surfactant structures, Classification of physical forces, van der Waals forces, Interaction between surfaces and particles, Electrostatic forces and electrical double layer, Surface force measurements, Colloid structure, mechanism of colloid formation, Sources of colloidal stability, Steric and Enthalpic stabilization, Coagulation kinetics, The complete interaction curve.

Surfactants and self-assembly, Micelles and critical micelle concentration, Adsorption in colloid and surface science, Adsorption theories, Adsorption from solution, Characterization methods of colloids- Kinetic properties and rheology, Optical properties, Scattering spectroscopy and Microscopy.

Capillarity-physical origin and measurement techniques, Introduction to wetting, Cassie and Wenzel models, Experimental studies of wetting phenomena, capillary length and shape of a liquid meniscus, Hysteresis and elasticity of triple lines, wetting in porous substrates, wetting at soft surfaces, Dewetting , smart surfaces.

Capillary driven transport and assembly, Chemical-gradient driven transport, Temperature-gradient driven transport, Capillary flows in an evaporating drop-Coffee ring effect, Reactive wetting, Electrokinetic transport phenomena, Electro-osmosis, Electrophoresis: Electrophoresis in solution, Electrophoresis of non-interacting solutes in gels.

References:

1. Morton Rosoff, Nanosurface chemistry, Marcel Dekker Inc., 2002.
2. Georgios M. Kontogeorgis, Soren Kiil, Introduction to applied colloid and surface chemistry, Wiley, 2016.
3. Arthur W. Adamson, Alice P. Gast, Physical chemistry of surfaces, John-Wiley &Sons, 2011.
4. de-Gennes P-G, Brochard-Wyart F., Quéré, D., Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls and Waves, Springer, 2004.
5. H. Watarai, N. Teramae, T. Sawada, Interfacial nanochemistry, Springer, 2005.
6. Mayers Drew, Surfaces, Interfaces and Colloids-Principles and applications, Wiley-VCH 1999.

MT6130E MICRO ELECTRO MECHANICAL SYSTEMS AND APPLICATIONS

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyze MEMS devices.
CO2: Appraise MEMS & NEMS fabrication techniques.
CO3: Assess the design and fabrication steps of MEMS devices.
CO4: Apply the MEMS for various applications.

Overview of micro electro mechanical devices and technologies. Introduction to architecture design, process flow, fabrication, packaging and testing. MEMS Fabrication, Deposition, lithography, and etching, Surface micromachining, Bulk micromachining, bonding technologies, LIGA technology and related fabrication methods

MEMS device concepts (micro sensors/actuators), Use of capacitive, inductive, optical, piezoresistive, piezoelectric methods for sensing. MEMS Applications, Accelerometers and gyroscope, Pressure sensors, Micro optics, Microsystems Packaging.

Introduction to existing and next-generation metrology tools for MEMS and NEMS inspection and qualification. Theoretical principles of metrology and experimental work on characterization of prototype MEMS and NEMS devices.

Cross-disciplinary application of MEMS and NEMS to the biological sciences. Interaction of living cells/tissues with nanofabricated structures, microfluidics for the movement and control of solutions - the development of I/O architectures for efficient readout of bioreactions.

References:

1. Mohamed Gad – el – Hak, The MEMS Handbook, Second Edition, CRC Press, 2005.
2. James J. Allen, Micro Electro Mechanical System Design, CRC Press, 2005.
3. K. Subramanian, Micro Electro Mechanical Systems: A Design Approach, Springer, 2008.

MT6131E MATERIALS FOR THERMAL MANAGEMENT AND ENERGY CONVERSION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Describe the characterisation and improvement of colloidal stability of nanofluids
CO2: Distinguish nanomaterials suitable for thermal management and energy conversion
CO3: Develop methods for designing engineering systems employing nanomaterials for solar thermal, refrigeration, phase change materials, desalination, etc.
CO4: Assess the application of nanomaterials for nanofuel, solar fuel, nanolubricants, etc.

Nanofluids- Synthesis of nano fluids- factors affecting stability- Zeta potential – Methods of stability measurement - Dynamic light scattering system – Acoustic Attenuation spectroscopy- Properties of nanofluids- thermal conductivity –viscosity – specific heat – wetting characteristics;
Convective heat transfer in nanofluids -Surface modified channels – Non-intrusive flow measurements in nanofluids – Ferrofluids - Influence of electric and magnetic field in nanofluid - Evaporation of nanofluids - boiling and condensation enhancement using modified surfaces and acoustic waves
Application of nanofluids in refrigeration and air conditioning, CO2 absorption

Nanomaterials for solar energy utilization: Solar thermal collectors – direct and surface absorption - Optical properties of nanofluids – extinction coefficient; Nanomaterials for solar thermal desalination - solar stills – floating absorber – RO desalination – Solar distillation – Atmospheric water harvesting
Solar fuels – photocatalytic CO_2 conversion – photocatalytic materials – high entropy materials – photocatalytic hydrogen synthesis.

Phase change materials (PCM) – Classification of PCM, Composite PCM, properties, Mini emulsion polymerization - Nano encapsulated phase change material, PCM based nanofluids; Applications of PCM - Electronics cooling, Battery cooling, Fuel cell cooling, solar panels, building materials, air conditioning, cold storage. Phase change thermal pads.

Fuels and fuel additives - catalytic nanoparticles – synthesis and characterization - cerium based mixed oxide nanoparticles - oxygen storage capacity – Temperature programme reduction –stability of nanofuel - diesel engine exhaust emissions – HC, CO, NOx, CO_2, smoke reduction, Catalyst coated diesel particulate filter- regeneration.
Lubricants and lubricant additives - solid lubricant additives – MoS_2/WS_2/graphene nanoparticles - synthesis and characterization - Friction and wear measurements- corrosion and wear resistant coatings.

References:

1. Sarit K. Das, Stephen U. Choi, Wenhua Yu, T. Pradeep, Nanofluids: Science and Technology, Wiley, 2007.
2. Vincenzo Bianco, Oronzio Manca, Sergio Nardini, Kambiz Vafai, Heat Transfer Enhancement with Nanofluids, CRC Press, 2017.
3. Amy S. Fleischer, Thermal Energy Storage Using Phase Change Materials: Fundamentals and Applications, Springer, 2015.
4. Mohsen Sheikholeslami and Davood Domairry Ganji, Applications of Nanofluid for Heat Transfer Enhancement, Elsevier, 2017.
5. S M Sohel Murshed, Carlos Nieto de Castro, Nanofluids: Synthesis, Properties and Applications, Nova Science Publishers, 2014.
6. Drew Myers, Surfaces Interfaces and Colloids, John Wiley & Sons, 1999.

MT6132E APPLIED TRANSMISSION ELECTRON MICROSCOPY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Evaluate Transmission electron microscope as a tool for the characterization and spectroscopy of various kinds of nanomaterials.
CO2: Analyse different parameters for the examination and interpretation of transmission electron microscopy data
CO3: Evaluate the state of art techniques in *in situ* TEM and their application

Interaction of electrons with matter; Introduction to TEM, brief history of TEM, basic construction of TEM, electron source, illumination system-lenses and apertures, projection system-lenses and apertures, beam specimen interaction, elastic and inelastic scattering, image formation in TEM, operating modes in TEM, bright field and dark field imaging, diffraction, scanning transmission electron microscopy (STEM), Sample preparation techniques, scattering and diffraction, scattering from a plane of atoms, reciprocal lattice, Ewald´s sphere.

Indexing of diffraction patterns, computation of intensity of diffraction patterns, different types of diffraction (Selected area, Kikuchi, Convergent Beam and nano-diffraction), contrast theory (kinematical and dynamical theory), imaging of different types of defects (zero, one, two- and three-dimensional defects), weak beam diffraction, phase contrast imaging, point resolution, envelop functions, lens aberrations and aberration correction; lattice imaging with atomic resolution.

Analytical techniques in TEM, Energy Dispersive Spectroscopy (EDS), Electron Energy Loss Spectroscopy (EELS), zero loss and low loss spectra, Energy Loss Near Edge Spectra (ELNES), Extended Energy Loss Fine Structure (EXEFLS), In *situ* techniques in TEM, state of the art, challenges and future, different types *of in situ* holders, *In situ* heating, *In situ* electrical biasing, *In situ* gas system, *In situ* liquid system, *In situ* straining, Sample preparation for *in situ* studies, special sample preparation for biological systems, beam damage and beam induced transformations.

References:

1. Williams D. B. & Carter C. B., Transmission Electron Microscopy, Springer US, 2009.
2. Von Heimendahl, M. Wolff U., Electron Microscopy of Materials: An Introduction Academic Press, 1980.
3. J.W. Edington, Practical Electron Microscopy in Materials Science, Van Nostrand Reinhold Company, 1991.
4. Xiaodong, Z. Hovmöller, H. and Oleynikov, P., Electron Crystallography: Electron Microscopy and Electron Diffraction, Oxford, 2011.
5. Fan, Zheng, et al. “In Situ Transmission Electron Microscopy for Energy Materials and Devices.” Advanced Materials, vol. 31, no. 33, Aug. p. 1900608, 2019.

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	IE6001E	Entrepreneurship Development	2	0	0	4	2
2.	ZZ6002E	Research Methodology	2	0	0	4	2
3.	MS6174E	Technical Communication and Writing	2	0	0	4	2

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

1. Kaplan, J. M., Warren, A. C., & Murthy V. Patterns of entrepreneurship management. John Wiley & Sons. (Indian Adoption) 2022.
2. Kuratko, D. F., Entrepreneurship: Theory, process, and practice. Cengage learning, 2016.
3. Barringer, B. R, Entrepreneurship: Successfully launching new ventures. Pearson Education India, 2015.
4. Rajiv Shah, Zhijie Gao, Harini Mittal, Innovation, Entrepreneurship, and the Economy in the US, China, and India, Academic Press, 2014.
5. Dr. K. Sundar, Entrepreneurship Development, 2nd Ed 2022 Vijaya Nichkol Imprints, Chennai
6. E. Gordon, Dr. K. Natarajan, Entrepreneurship Development, 6th Ed, Himalya Publishers,Delhi, 2017.
7. Debasish Biswas, Chanchal Dey, Entrepreneurship Development in India, T & F group, 2021.

ZZ6002E RESEARCH METHODOLOGY

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Explain the basic concepts and types of research.
CO2: Develop research design and techniques of data analysis
CO3: Present research to the scientific community
CO4: Develop an understanding of the ethical dimensions of conducting research.

Exploring Research Inquisitiveness
Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation.

Data Analysis
Literature review :Tools and Techniques, Collection and presentation of data, processing and analysis of data, Descriptive statistics and inferential statistics, Measures of central tendency, dispersion, skewness, asymmetry, Probability distributions, Single population and two population hypothesis testing, Parametric and non-parametric tests, Design and analysis of experiments: Analysis of Variance (ANOVA), completely randomized design, Measures of relationship: Correlation and regression, simple regression analysis, multiple regression, interpretation of results, Heuristics and simulation.

Research writing and Ethics
Reporting and presenting research, Paper title and keywords, writing an abstract, writing the different sections of a paper, revising a paper, responding to peer reviews.

The codes of ethics, copyright, patents, intellectual property rights, plagiarism, citation, acknowledgement, avoiding the problems of biased survey.

References:

1. Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M., Management Research Methodology, Pearson Education, 2006.
2. Leedy, P, D., Practical Research: Planning and Design, Pearson, 2018.
3. Kothari, C.R., Research Methodology – Methods and Techniques, New Age International Publishers, 2004
4. Mike Martin, Roland Schinzinger, Ethics in Engineering, Mc Graw Hill Education, 2004.
5. Vinod V Sople, Managing Intellectual Property-The Strategic Imperative, EDA Prentice of Hall Pvt. Ltd., 2014.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: NIL

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.
CO2: Collaborate on various writing projects for academic and technical purposes.
CO3: Combine attributes of critical thinking for improving technical documentation.
CO4: Adapt technical writing styles to different platforms.

Technical Communication
Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics
Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation
Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. Foley, M., & Hall, D., Longman advanced learner's grammar, a self-study reference & practice book with answers Pearson Education Limited, 2018.
2. Gerson, S. J., & Gerson, S. M., Technical writing: Process and product, Pearson, 2009.
3. Kirkwood, H. M. A., & M., M. C. M. I., Hallidays introduction to functional grammar, Hodder Education, 2013.
4. Markel, M., Technical Communication, Palgrave Macmillan, 2012.
5. Tuhovsky, I., Communication skills training: A practical guide to improving your social intelligence, presentation, Persuasion and public speaking skills, Rupa Publications India, 2019.
6. Williams, R., The Non-designer's Design Book, Peachpit Press, 2014.