MASTER OF TECHNOLOGY
IN
MATERIALS SCIENCE & TECHNOLOGY
(Applicable from the academic session 2018-2019)

MAULANA ABUL KALAM AZAD
UNIVERSITY OF TECHNOLOGY,
WEST BENGAL

Utech

In Pursuit Of Knowledge And Excellence

Maulana Abul Kalam Azad University of Technology, West Bengal
(Formerly West Bengal University of Technology)
Haringhata-741249, Nadia, West Bengal, INDIA

Maulana Abul Kalam Azad University of Technology, West Bengal

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MASTER OF TECHNOLOGY IN

MATERIALS SCIENCE & TECHNOLOGY PROGRAMME

Curriculum Structure

Sl No.	Category	Subject Code	Subject Name	Total Number of contact hours L	T	P	Credits
Semester-I							
Theory							
1	Program Core I	MST101	Introduction to Materials Science and Technology	4	1	0	4
2	Program Core II	MST102	Mechanical Behavior of Material	4	1	0	4
3	Program Core III	MST103	Electronic, Optical and Magnetic Properties of Materials	4	1	0	4
4	Program Core IV	MST104	Fundamentals of Materials Processing	4	1	0	4
5	Mandatory Learning Course	MLC101	Research Methodology and IPR	2	1	0	2
	Total Theory			18	5	0	18
Practical							
1	Laboratory I	MST191	Characterization of Materials	0	0	4	2
	Total Practical			0	0	4	2
Sessional							
1	Mini Project	MST181	Mini Project with Seminar	2	0	0	2
			Total of Semester-I	20	5	4	22
Semester-II							
Theory							
1	Program Core V	MST201	Nanostructures and Nanomaterials	4	1	0	4
2	Program Core VI	MST202	Mathematics for Materials Science and Technology	3	1	0	3
3	Program Elective I	MST203 A/B/C	Program Elective I	2	1	0	2
4	Open Elective I	MST204 A/B/C	Open Elective I	2	1	0	2
	Total Theory			11	4	0	11
Practical							
1	Laboratory I	MST291	Synthesis, Fabrication and Processing of Materials	0	0	6	3
	Total Practical			0	0	6	3
Sessional							
1	Mini Project	MST281	Mini Project with Seminar	2	0	0	2
			Total of Semester-II	13	4	6	16

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Semester-III							
Sl No.	**Category**	**Subject Code**	**Subject Name**	**Total Number of contact hours**			**Credits**
				L	**T**	**P**	
Theory							
1	Program Core VII	MST301	Material and Energy Balances	3	1	0	3
2	Open Elective II	MST302 A/B/C	Open Elective II	2	1	0	2
	Total Theory			5	2	0	5
Sessional							
1	Major Project	MST381	Dissertation-I (Progress)	0	0	20	10
			Total of Semester-III	5	2	20	15
Semester-IV							
Theory							
1	Program Core VIII	MST401	Medical Biomaterials	3	1	0	3
2	Program Elective II	MST402 A/B/C	Program Elective II	2	1	0	2
Sessional							
1	Major Project	MST481	Dissertation-II (Completion)	0	0	20	10
			Total of Semester-IV	5	2	20	15
Total Credits for the Programme							68

Students will go for internship/industrial training during semester break (between II & III)

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List of Program Electives

- **Program Elective – I**

1. Materials Data Science and Informatics (MST203A)
2. Computational Materials Science and Engineering (MST203B)
3. Atoms to Materials: Predictive Theory and Simulations (MST203C)

- **Program Elective – II**

1. Waste Management and Critical Raw Materials (MST402A)
2. Waste Materials to Energy Conversion (MST402B)
3. E-Waste Materials and Its Management (MST402C)

List of Open Electives

- **Open Elective – I**

1. Introduction to Artificial Intelligence (MST204A)
2. Block Chain Technology (MST204B)
3. Principles of Machine Learning (MST204C)

- **Open Elective – II**

1. Micro and Nanofabrication (MST302A)
2. Internet of Things: Sensor and Devices (MST302B)
3. Internet of Things: Sensing and Actuation from Devices (MST302C)

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LIST OF MOOCS EQUIVALENT OF COURSES OF CURRICULUM FOR CREDIT TRANSFER

Classroom Equivalent Online Courses offered for M. Tech. in Materials Science & Technology

Programme Core						
Course Title (Theory)	Credit as in Syllabus	MOOCS Equivalent (Theory)	Provided by	Duration (week)	Credit	Name of University/Institute
Introduction to Materials Science and Technology	4	Introduction to Materials Science and Engineering	NPTEL	12	4	IIT, BHU
Mechanical Behaviour of Material	4	Mechanical Behaviour of Material	edx	14	4	MIT
Electronic, Optical and Magnetic Properties of Materials	4	Electronic, Optical and Magnetic Properties of Materials	edx	15	4	MIT
Fundamental of Materials Processing	4	Fundamental of Materials Processing-I Fundamental of Materials Processing-II	NPTEL	16	4	IIT, Kanpur
Nanostructures and Nanomaterials	4	Nanostructures and Nanomaterials: Characterization and Properties	NPTEL	15	4	IIT, Kanpur
Mathematics for Materials Science and Technology	3	Learn Mathematica Now	Udemy	9	3	Udemy
Material and Energy Balances	3	Material and Energy Balances	NPTEL	12	3	IIT Madras
Medical Biomaterials	3	Medical Biomaterials	NPTEL	8	3	IIT Madras
Programme Elective						
Materials Data Science and Informatics	2	Materials Data Science and Informatics	Coursera	5	2	Georgia Institute of Technology
Computational Materials Science and Engineering	2	Computational Materials Science and Engineering	nanoHUB	6	2	University of Illinois
Atoms to Materials: Predictive Theory and Simulations	2	From Atoms to Materials: Predictive Theory and Simulations	nanoHUB	5	2	Purdue University
Waste Management and Critical Raw Materials	2	Waste Management and Critical Raw Materials	edx	6	2	TU DELFT
Waste Materials to Energy Conversion	2	Waste to Energy Conversion	NPTEL	8	2	IIT Roorkee
E-Waste Materials and Its Management	2	Electronic Waste Management-Issues and Challenges	NPTEL	4	2	IIT Kharagpur

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Curriculum Structure

LIST OF MOOCS EQUIVALENT OF COURSES OF CURRICULUM FOR CREDIT TRANSFER

Classroom Equivalent Online Courses offered for M. Tech. in Materials Science & Technology

Open Elective						
Course Title (Theory)	Credit as in Syllabus	MOOCS Equivalent (Theory)	Provided by	Duration (week)	Credit	Name of University/Institute
Introduction to Artificial Intelligence	2	Introduction to Artificial Intelligence	edx	4	2	Microsoft
Block Chain Technology	2	Block Chain Technology	edx	6	2	Berkey, University of California
Principles of Machine Learning	2	Principles of Machine Learning	edx	6	2	Microsoft
Micro and Nanofabrication	2	Micro and Nanofabrication	edx	7	2	University of Lausanne
Internet of Things: Sensor and Devices	2	IoT Sensor and Devices	edx	5	2	Curtin University
Internet of Things: Sensing and Actuation from Devices	2	Internet of Things: Sensing and Actuation from Devices	Coursera	6	2	UC SanDiego
Mandatory Learning Course						
Research Methodology & IPR	2	Understanding Research Methods	Coursera	4	2	University of London
		Intellectual Property Law and Policy: Part-I	edx	6		University of Pennsylvania

Subject Code: MST101	**Category:** Program Core I
Subject Name: Introduction to Materials Science and Technology	**Semester:** First
L-T-P: 4-1-0	**Credit:** 4
Pre-Requisties: Basic Knowledge of Physics, Chemistry, Maths, Elementary knowledge of Materials Engineering.	

COURSE OBJECTIVE:

This course will introduce basic concepts of microstructure, defects of crystalline materials, transformations, heat treatments and mechanical behavior of materials.

COURSE OUTLINE:

1. Crystal Structure: Crystal systems. Bravais lattices. Symmetry. Miller indices of directions and planes. Bragg's Law. Close-Packed structures: CCP, HCP. Voids in close-packed structures.

2. Lattice Imperfections: Coordination no, Atomic Packing Factor, Packing density, Hexagonal close packed structure. Point defect. Line defect. Surface Defect. Volume defect.

3. Classification of Materials: Level of Structure. Metallic Alloys, Ceramic Materials, Polymeric Materials, Magnetic Materials, Electronic Materials.

4. Diffusion: Fick's First and Second Laws. Atomistic mechanisms of diffusion: interstitial and substitutional diffusion. Diffusion paths: lattice, grain boundary, Steady vs. unsteady state diffusion.

5. Phase Transformation: Phases and components. Phases present in the system. Composition of phases. Gibbs phase rule. Invariant reactions. Nucleation and capillary rise. Growth and overall transformation.

6. Dislocation & Strengthening Mechanism: Dislocation loop, dislocation node, dislocation motion: glide, climb and cross slip. 2D defects. Strengthening mechanisms: strain hardening, grain size hardening, solid solution hardening and age hardening. Dislocation density. Recovery, Recrystallisation, Grain Growth.

7. Properties of Materials: Mechanical behaviour of materials. Tensile test. Plastic deformation and crystal structure. Slip. Resolved shear stress and critical resolved shear stress: True stress and true strain. Creep. Creep mechanisms. Fracture. Toughening of glass: tempering and ion-exchange. Fatigue. Sub-critical crack growth.

LEARNING RESOURCES:

1. Introduction to Materials Science and Engineering-Web course---http://nptel.iitm.ac.in
2. Mechanical Metallurgy, George E Dieter. Mcgraw Hill, London.
3. Hyperlinks:

A. http://neon.mems.cmu.edu/cramb/Processing/history.html

B. http://users.encs.concordia.ca/~woodadam/MECH221/ Course_Notes/Crystal%20directions%20 and%20planes.pdf

C. http://www.tulane.edu/~sanelson/eens211/introsymmetry.html

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DETAILED SYLLABI OF MASTER OF TECHNOLOGY
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Subject Code: MST102	**Category**: Program Core II
Subject Name: Mechanical Behaviour of Materials	**Semester**: First
L-T-P: 4-1-0	**Credit**: 4
Pre-Requisties: Engineering Metallurgy, Strength of Materials	

COURSE OBJECTIVE:

This course will provide knowledge on the mechanical behavior of materials, from the continuum description of properties to the atomistic and molecular mechanisms that confer those properties to all materials.

COURSE OUTLINE:

1. Stress-strain behaviour of materials: Stress and strain, Normal and shear stress, Normal and shear strain, Hooke's law for isotropic materials, 3D stress states, Stress strain curves for engineering materials,

Strain energy, Mohr's circles, stress-strain relations-elastic, strain energy, plasticity, yield criteria.

2. Forming: Fundamentals, classification, flow stress, flow curves, effect of parameters such as strain rate, temperature etc, workability, anisotropy. Anisotropic materials and symmetry. Composite materials.

Forging. Rolling. Extrusion. Wire Drawing. Defects in metal forming processes. Powder forming and other non-conventional forming methods.

3. Elasticity: Bonding between atoms; Linear viscoelasticity: Spring-dashpot models. Dynamic mechanical measurements. Molecular basis for linear viscoelasticity. Viscoelasticity in biomaterials. Energetic basis for linear elaticity. Rubber elasticity: entropic basis for non-linear elasticity. Plasticity yield criteria.

4. Dislocations: Dislocation mechanics Hardening mechanisms. Beam deflection.

5. Deformation: Deformation zone geometry, friction, residual stress. Deformation mechanism. Creep in crystalline materials. Mechanisms of creep. Creep fracture. Fracture mechanics. Mechanisms of fast fracture Fatigue.

LEARNING RESOURCES:

1. A.S.M. Handbook-Vol. 14, Forming and Forging, ASM International.
2. Metal Forming Handbook, Schuler, Springer Berlin Heidelberg.
3. Metal Forming Science and Practice, Ed. John G Lenard, Elsevier Science Ltd., U.K.
4. Hyperlink:

https://www.edx.org/course/mechanical-behavior-materials-part-1-mitx-3-032-1x-1

https://www.edx.org/course/mechanical-behavior-materials-part-1-mitx-3-032-1x-2

https://www.edx.org/course/mechanical-behavior-materials-part-1-mitx-3-032-1x-3

**DETAILED SYLLABI OF MASTER OF TECHNOLOGY
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Subject Code: MST103	**Category**: Program Core III
Subject Name: Electronic, Optical and Magnetic Properties of Materials	**Semester**: First
L-T-P: 4-1-0	**Credit**: 4
Pre-Requisties: Differential and Integral Calculus, Electricity and Magnetism, Structure and Bonding in solid state materials.	

COURSE OBJECTIVE:

This course will develop knowledge on the fundamental principles of quantum mechanics, solid state physics, and electricity and magnetism. These principles will help to describe the origins of the electronic, optical, and magnetic properties of materials, and how these properties can be engineered to suit particular applications, including diodes, optical fibers, LEDs, and solar cells.

COURSE OUTLINE:

1. Lattice Vibrations: Hamiltonian Mechanics, Vibrations in Crytals-Phonons, Elastic Bandgap.

2. Quantum Mechanics: Schrodinger's Equation, 1-Dimensional Problems, Measurements-The Ehrenfest Theorem, Three Dimensions-Hydrogen Atom.

3. Electronic Band Structures: Periodic Potential, Central Equation, Understanding Band Diagrams, Engineering conductivity in Semiconductors.

4. Solid-State Devices: PN Junctions, Solar Cells, LEDs.

5. Optical Properties: Wave Equation, E/M Waves at Interfaces, Photonic Crystals.

6. Introduction to Magnetism: Classification of Magnets, Hysteresis in Ferromagnetic materials, Magnetic Domains.

LEARNING RESOURCES:

1. Electronic, Magnetic, and Optical Materials (Advanced Materials and Technologies)-Pradeep Fulay & Jung-Kun Lee, CRC Press, Taylor & Francis Group.

2. Hyperlink: https://www.edx.org/course/electronic-optical-magnetic-properties-mitx-3-024x

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DETAILED SYLLABI OF MASTER OF TECHNOLOGY
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Subject Code: MST104	**Category**: Program Core IV
Subject Name: Fundamental of Materials Processing	**Semester**: First
L-T-P: 4-1-0	**Credit**: 4
Pre-Requisties: Under graduate level Mathematics, Thermodynamics.	

COURSE OBJECTIVE:

Various materials processes are used in variety of industries to create and form materials for wide range of applications. There are some commonalities behind all these processes and the aim of this course is to go through these fundamental physics and materials science behind these processes so as to be able to understand, design and predict the outcome of these methods.

COURSE OUTLINE:

1. Heat Flow: Fundamentals of Heat Flow, Thermal Resistance, Relationship to Thermodynamics, Unidirectional Heat flow.

2. Solidification: Introduction to Solidification. Composition Variation-Plane Front Solidification, Cellular solidification in Single phase alloys, Plane front solidification of polyphase alloys; Fluid Flow.

3. Powder Processing: Introduction to Powder Processing; Powder characterization, Powder Fabrication; Powder Consolidation, Powder compaction; Sintering.

4. Metal Working: Stress and Strain Analysis and Yield Criteria, Plastic Instability and Superplasticity, Mechanics of metal working, Friction and Formability and Case Studies.

5. Thin film deposition: Introduction to Vacuum Technology; PVD, Introduction to Plasma, PVD-Sputtering, Chemical Vapor Deposition, Special techniques and applications.

LEARNING RESOURCES:

1. W. Kurz and D.J. Fisher, Fundamentals of Solidification, CRC Press, 1998.
2. A. Upadhyaya, G.S. Upadhyaya, Powder Muetallurgy: Science Technology and Materials, 2011
3. G.E. Dieter, Mechanical Metallurgy, McGraw Hill, Inc., London, UK, 1992.
4. Thin Film Deposition – Principles and Practice by Donald L. Smith
5. Hyperlink:

A. https://onlinecourses.nptel.ac.in/noc16_mm11

B. https://onlinecourses.nptel.ac.in/noc17_mm02

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DETAILED SYLLABI OF MASTER OF TECHNOLOGY

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Subject Code: MST201	**Category**: Program Core V
Subject Name: Nanostructures and Nanomaterials	**Semester**: Second
L-T-P: 4-1-0	**Credit**: 4
Pre-Requisties: Knowledge of Materials Science and Engineering	

COURSE OBJECTIVE:

This course will provide an overview of nanostructures evincing their fascinating properties (mechanical, optical, electromagnetic, chemical, and biological) unseen otherwise. The hierarchical development from nano to macro length scale, its adoption in nature (biomimicking), understanding the change in crystal structure and defects therein, thermodynamics and Structural, phase, microstructural and mechanical characterization techniques will be dealt in detail.

COURSE OUTLINE:

Overview of Nanostructures and Nanomaterials: classification, Crystalline nanomaterials and defects therein. Hybrid nanomaterials, Multiscale hierarchical structures built out of nanosized building blocks (nano to macro).Nanomaterials in Nature: Nacre, Gecko,Teeth. Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires, Quantum Dots. Applications of nanostructures. Reinforcement in Ceramics, Drug delivery, Giant magnetoresistance, etc. Cells response to Nanostructures. Surfaces and interfaces in nanostructures. Ceramic interfaces, Superhydrophobic surfaces, Grain boundaries in Nanocrystalline materials, Defects associated with interfaces. Thermodynamics of Nanomaterials. Overview of properties of nanostructures and nanomaterials. How the performance of nanomaterials come about: sizestructure-Mechanism-property-performance pathway. Overview of characterization of nanostructures and nanomaterials. Focus on: Brunauer-Emmett-Teller (BET) technique, Transmission Electron Microscopic techniques, Auger Electron Spectroscopy, X-ray Photoelectron Spectroscopy. Electron Energy Loss Spectroscopy. Deformation behaviour of nanomaterials. Fracture and creep. Nanomechanics and nanotribology. Electrical, Magnetic and Optical properties.

LEARNING RESOURCES:

1. Encyclopedia of Nanoscience and Nanotechnology, Ed.:Hari Singh Nalwa, American Scientific Publishers, 2004.
2. Hyperlink: nptel.ac.in/courses/118104008/

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Subject Code: MST202	**Category**: Program Core VI
Subject Name: Mathematics for Materials Science and Technology	**Semester**: Second
L-T-P: 3-1-0	**Credit**: 3
Pre-Requisties: Basic concepts in algebra and calculus.	

COURSE OBJECTIVE:

This course will provide knowledge on the use of many of the inbuilt Wolfram Language functions, solve algebraic equations, compute solutions to differentiation and integration, write functions to enhance the use of the Wolfram Language, import and manipulate data and graph plots.

COURSE OUTLINE:

Introduction to this course, The Mathematica notebook, Getting Mathematica, The fancy calculator, Simple arithmetic, Powers and order of arithmetical operation, Trigonometric functions, Collections, The Table function, Manipulating lists, Applying functions to a list, Applying more functions to a list, The Grid function, Algebra and linear algebra, Solving polynomial equations, Transcendental functions and numerical solutions, Vectors, Matrices, Calculus, Derivatives, Derivatives of functions, Limits, Integration, Plotting mathematical functions, Manipulation, Plotting created functions, Plots in 3D, Labels and legends, More labels and legends, Discrete plots and list plots, Function notation, Shorthand notation, The replace operator, Working with data, Data and datasets, Addressing data.

LEARNING RESOURCES:

1. Essentials of Programming in Mathematica: Paul Wellin, Cambridge University Press, 2016, ISBN: 9781107116665.
2. Hyperlink: https://www.udemy.com/mathematica/

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Subject Code: MST301	**Category**: Program Core VII
Subject Name: Material and Energy Balances	**Semester**: Third
L-T-P: 3-1-0	**Credit**: 3
Pre-Requisties: Basic knowledge of Science	

COURSE OBJECTIVE:

This course will introduce the basics of material and energy balances and their applications in chemical and bioprocess industries by using examples primarily based on chemical and biochemical operations, and other biological systems.

COURSE OUTLINE:

Introduction; Units and dimensions; Basic terminologies. Fundamentals of Material Balances; Material Balances for Single Units Without Reactions. Material Balances for Multiple Units Without Reactions; Material Balances for Reactive Processes. Material Balances for Reactive Processes; Combustion Reactions. Material Balances for Systems with Recycle, Bypass, and Purge. Energy Balance Terminologies; Introduction to Energy Balances. Mechanical Energy Balances; Objectives and Procedures for Energy Balances. Energy Balances on Nonreactive Processes without Phase Change. Energy Balances on Nonreactive Processes with Phase Change. Mixing and Solutions; Fundamentals for Energy Balances on Reactive Processes. Energy Balances on Reactive Processes.
Material and Energy Balances for Unsteady State Processes.

LEARNING RESOURCES:

1. David M. Himmelblau and James B. Riggs, Basic Principles and Calculations in Chemical Engineering, 7th Edition, Publisher: Prentice Hall India
2. Richard M. Felder and Ronald W. Rousseau, Elementary Principles of Chemical Processes, 3rd edition, Publisher: John Wiley & Sons
3. Pauline Doran, Bioprocess Engineering Principles, 2nd Edition, Publisher: Academic Press
4. Ann Saterbak, Ka-Yiu San, Larry V. McIntire, Bioengineering Fundamentals, Publisher: Pearson
5. Hyperlink: https://onlinecourses.nptel.ac.in/noc18_bt29/preview

DETAILED SYLLABI OF MASTER OF TECHNOLOGY
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Subject Code: MST401	**Category**: Program Core VIII
Subject Name: Medical Biomaterials	**Semester**: Fourth
L-T-P: 3-1-0	**Credit**: 3
Pre-Requisties: Nil	

COURSE OBJECTIVE:

Biomaterial is any natural or synthetic material used to replace or augment a part of the body so that it improves the human health by restoring the function of the natural living tissue or organ. It should be biocompatible and should not cause any adverse systemic reaction to the host. It could be a polymer,metal,ceramic or combination of these. It may have to be in contact or remain in the body for few hours or for rest of the life of the person.

COURSE OUTLINE:

Introduction to Biomaterials, Mechanical and Physico-mechanical Properties, Resorbability, Biodegradation, Biofilm, Material characterization-Analytical instruments, Biological responses, compatibility, cytotoxicity, Proteins, Tissue and blood Response, Cell-biomaterial interaction, Animal trials (in vivo), Metals-types, classifications, applications, Metals- properties, Metals Polymers-types, classifications, applications, Polymers, Blends/composites, Biopolymers, Hydrogels, Preparation of different morphologies (with experiments), Surface modifications (with experiments), Ceramics, Drug delivery systems/encapsulation, Biomaterials for cardiovascular/pulmonary/ophthalmological applications, Biomaterials for urinary/dental/skin applications, Sterilization of implants, device failures, unique issues, conclusion.

LEARNING RESOURCES:

1. David M. Himmelblau and James B. Riggs, Basic Principles and Calculations in Chemical Engineering, 7th Edition, Publisher: Prentice Hall India

2. Richard M. Felder and Ronald W. Rousseau, Elementary Principles of Chemical Processes, 3rd Edition, Publisher: John Wiley & Sons

3. Pauline Doran, Bioprocess Engineering Principles, 2nd Edition, Publisher: Academic Press

4. Ann Saterbak, Ka-Yiu San, Larry V. McIntire, Bioengineering Fundamentals, Publisher: Pearson

5. Hyperlink: https://onlinecourses.nptel.ac.in/noc18_bt29/preview

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Subject Code: MST203A	**Category**: Program Elective I
Subject Name: Materials Data Science and Informatics	**Semester**: Second
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Statistics, Informatics and Data Science	

COURSE OBJECTIVE:

This course aims to provide a succinct overview of the emerging discipline of Materials Informatics at the intersection of materials science, computational science, and information science. Attention is drawn to specific opportunities afforded by this new field in accelerating materials development and deployment efforts. A particular emphasis is placed on materials exhibiting hierarchical internal structures spanning multiple length/structure scales and the impediments involved in establishing invertible process-structure-property (PSP) linkages for these materials. More specifically, it is argued that modern data sciences (including advanced statistics, dimensionality reduction, and formulation of metamodels) and innovative cyberinfrastructure tools (including integration platforms, databases, and customized tools for enhancement of collaborations among cross-disciplinary team members) are likely to play a critical and pivotal role in addressing the above challenges.

COURSE OUTLINE:

1. Accelerating Materials Development and Deployment: Why Accelerate Material Discovery and Development, Historical Materials Development Cycles, How do we accelerate materials development and deployment?, Emergence of multi-stakeholder initiatives, The Materials Innovation Ecosystem, Multiscale Modeling and Multilevel Design of Materials, Decision-Making in Material Design, Multilevel Systems-Based Materials Design.

2. Materials Knowledge and Materials Data Science: Material Property, Material Structure, and Manufacturing Processes, Process-Structure-Property (PSP) Linkages, Role of Structures in PSP Linkages, Data Science Terminology, Main Components of Data Science, What is Big Data?

3. Materials Knowledge Improvement Cycles: Digital Representation of Material Structure, Spatial Correlations: n-Point Statistics, Computation and Visualization of 2-Point Spatial Correlations, Principal Component Analyses (PCA) for low dimensional representations, Principal Component Analyses (PCA) for low dimensional representation of material structure, Homogenization: Passing Information to Higher Length Scales.

4. Case Study in Homogenization: Plastic Properties of Two-Phase Composites: Structure-Property Linkages using a Data Science Approach-Part 1, Structure-Property Linkages using a Data Science Approach-Part 2.

5. Materials Innovation Cyberinfrastructure and Integrated Workflows: Materials Innovation Ecosystem, Materials Innovation Cyberinfrastucture, e-Collaboration Platforms/Environments, Materials Cyber-Infrastructure, Introduction to PyMKS Materials Knowledge Systems in Python, Materials Data Science with PyMKS.

6. Practice Exercise:

Accelerating Materials Development and Deployment, Materials Knowledge and Materials Data Science, Materials Knowledge Improvement Cycles, Case Study in Homogenization: Plastic Properties of Two-Phase Composites, Materials Innovation Cyberinfrastructure and Integrated Workflows.

LEARNING RESOURCES:

1. Informatics for Materials Science and Engineering. Data-driven Discovery for Accelerated Experimentation and Application, Ed: Krishna Rajan, Elseiver.
2. Hyperlink: https://www.coursera.org/learn/material-informatics

Subject Code: MST203B	**Category**: Program Elective I
Subject Name: Computational Materials Science and Engineering	**Semester**: Second
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Statistics and Data Science	

COURSE OBJECTIVE:

This course will provide hands-on experience with popular computational materials science and engineering software through a series of projects in: electronic structure calculation (e.g., VASP), molecular simulation (e.g., GROMACS), phase diagram modeling (e.g., Thermo-Calc), finite element modeling (e.g., OOF2), and materials selection. The course will familiarize students with a broad survey of software tools in computational materials science, scientific computing, and prioritize the physical principles underlying the software to confer an understanding of their applicability and limitations.

COURSE OUTLINE:

CMSE: Introduction, Computer models of Materials, MatSE in Multiscale, ICME, Moore's Law, What is driving CMSE, Materials Genome Initiative, bash: Introduction, Linux, bash basics, bash cell, special symbols, bash utilities, integer arithmatic, ssh, scp & sstp, vi/vim, installing software, bash scripting, anatomy of script, MATLAB, Density Functional Theory (DFT), Molecular Dynamics (MD), Finite Element Method (FET), Calculation of Phase Diagram (CALPHAD).

LEARNING RESOURCES:

1. Computational materials science: Surfaces, interfaces, crystallization: A.M. Ovrutsky, A.S. Prokhoda, and M.S. Rasshchupkyna: Elsevier, 2013
2. Introduction to Computational Materials Science: Fundamentals to Applications: R. LeSar, Cambridge University Press, 2013.
3. Hyperlink: https://nanohub.org/resources/22124

Subject Code: MST203C	**Category**: Program Elective I
Subject Name: Atoms to Materials: Predictive Theory and Simulations	**Semester**: Second
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Basic knowledge of classical mechanics, thermodynamics, calculus and algebra.	

COURSE OBJECTIVE:

This course will develop a unified framework for understanding essential physics that govern materials at atomic scales and relate these processes to the macroscopic world. The course will cover important applications, trends, and directions.

COURSE OUTLINE:

Quantum Mechanics and Electronic Structure: Why Quantum Mechanics? Basic Quantum Mechanics of Electronic Structure, Quantum Well, Quantization, and Optical Processes, The Hydrogen Atom, Excited States of Hydrogen and Multi-Electron Atoms; Electronic Structure and Bonding of Molecules and Crystals: The Nature Chemical Bond, Structure of Simple Hydrides, Linear Combination of Atomic Orbitals, Electronic Structure of Crystals, Electronic Band Structures, Electronic Structure Review; Dynamic of Atoms: Classical Mechanics and MD Simulations: What is Molecular Dynamics? Interatomic Potentials for Molecular Materials: Covalent Interactions; Interatomic Potentials for Molecular Materials: Van Der Waals and Electrostatic Interactions, Potentials for Metals and Semiconductors, Normal Modes and Phonons, Connecting Atomic Processes to the Macroscopic World-Vibrations, Optical, and Dielectric Response, Thermo-mechanical Properties; Statistical Mechanics: Connecting the Micro and Macro Worlds, The Canonical Ensemble and Microscopic Definition of T, Statistical Mechanics of the Harmonic Solid, The Quantum Harmonic Solid, Isothermal and Isobaric MD Simulations, Quantum Statistical Mechanics of Electronics; Case Studies: Ab Initio Electronic Structure Calculations, Hartree-Fock and Exchange Interaction, Density Functional Theory, Reactive Interatomic Potentials, Non-Equilibrium MD Simulation, Thermal Transport.

LEARNING RESOURCES:

1. Computer Simulation of Materials at Atomic Level, Ed: P. Deak, T. Frauenheim, M. R. Pederson, Wiely, 2005.
2. Hyperlink: https://nanohub.org/courses/FATM

Subject Code: MST402 A	**Category**: Program Elective II
Subject Name: Waste Management and Critical Raw Materials	**Semester**: Fourth
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Knowledge of Waste Management.	

COURSE OBJECTIVE:

A good number of the materials found in everyday products are now referred to as "critical". This means that there is a risk of failure in their supply and that they are also critical in terms of economic importance. Innovative product design and reusing, recycling and remanufacturing products can help to deal with a raw materials shortage. This course provides knowledge on recycling technologies and more efficient ways of collecting and recycling critical raw materials (CRMs) to deal with a raw materials shortage. This course will help to get practical knowledge of the circular economy, recycling, refurbishment, and remanufacturing as a means of identifying new business opportunities.

COURSE OUTLINE:

Urgency and challenges with critical raw materials (CRMs) and waste. How can we find out what CRMs are in products, and how can we get them back? The effects of materials shortage, future development and geo-politics on raw materials. Current waste management of products containing CRMs in general, waste management of commercial and household waste, regulation of electric and electronic waste (WEEE). Environmental problems such as leaching heavy metals from incinerator ashes and landfills. Partial metals retrieval from incinerator ashes. Different collection systems for recycling and remanufacturing/refurbishment, recycling psychology and the separate waste collection of commercial and household waste. Recycling technology: pre-processing, metallurgy and its challenges. Recycling economics and the problem of <1% (most) CRMs recycling. Remanufacturing and refurbishment systems: return of product (reverse logistics), disassembly and repair of the product, market demand and economics. Product design using better recycling or remanufacturing and refurbishment. Substitution of materials. New business models to generate profits from products that last longer. Circular procurement for government and companies.

LEARNING RESOURCES:

1. Integrated Life-Cycle and Risk Assessment for Industrial Processes and Products (Advanced Methods in Resource & Waste Management), Ed: G. Sonnemann, M. Tsang and M. Schuhmacher, Talyor and Francis, 2018.
2. Hyperlink: https://www.edx.org/course/waste-management-recycling-and-critical-raw-materials

Subject Code: MST402 B	**Category**: Program Elective II
Subject Name: Waste to Energy Conversion	**Semester**: Fourth
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Knowledge of Waste Management	

COURSE OBJECTIVE:

The course deals with the production of energy from different types of wastes through thermal, biological and chemical routes. It is intended to help the young scientific professionals to keep their knowledge upgraded with the current thoughts and newer technology options along with their advances in the field of the utilization of different types of wastes for energy production.

COURSE OUTLINE:

Introduction, characterization of wastes. Energy production form wastes through incineration, energy production through gasification of wastes. Energy production through pyrolysis and gasification of wastes, syngas utilization. Densification of solids, efficiency improvement of power plant and energy production from waste plastics. Energy production from waste plastics, gas cleanup. Energy production from organic wastes through anaerobic digestion and fermentation, introduction to microbial fuel cells. Energy production from wastes through fermentation and transesterification. Cultivation of algal biomass from wastewater and energy production from algae.

LEARNING RESOURCES:

1. Rogoff, M.J. and Screve, F., "Waste-to-Energy: Technologies and Project Implementation", Elsevier Store.
2. Young G.C., "Municipal Solid Waste to Energy Conversion processes", John Wiley and Sons.
3. Harker, J.H. and Backhusrt, J.R., "Fuel and Energy", Academic Press Inc.
4. EL-Halwagi, M.M., "Biogas Technology- Transfer and Diffusion", Elsevier Applied Science.
5. Hall, D.O. and Overeed, R.P.," Biomass - Renewable Energy", John Willy and Sons.
6. Hyperlink: https://onlinecourses.nptel.ac.in/noc17_ch05/preview

Subject Code: MST402 C	**Category**: Program Elective II
Subject Name: E-Waste Materials and Its Management	**Semester**: Fourth
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Knowledge of E-Waste	

COURSE OBJECTIVE:

This course will discuss the overall scenario of E-Waste management in India in comparison with other countries around the globe. This course provides knowledge on the effects of recycling and management of Electronic Waste on human health, environment and society; the risk assessment owing to pollutants released from E-Waste recycling in soil, air and water; possible option of extraction of Rare-Earth Minerals and life-cycle analysis for a possible sustainable solution of E-Waste Management for cutting the ill-effects of informal recycling.

COURSE OUTLINE:

Composition of E-Waste and its generation rates across the world; Exposure pathway of pollutants emitted from Recycling of E-Waste; The various processes of informal E-Waste management and its ill-effects on health and society; E-Waste Management Rules of India, Formal Metal extraction processes from E-Waste; Life-Cycle-Analysis (LCA) and sustainable engineering from electrical and electronics industry perspectives. The existing E-Waste Management rules in India and comparison with other countries around the world, the Extended Producer Responsibility (EPR) and other take-back system, E-waste Management: Case Studies and Unique Initiatives from around the World.

LEARNING RESOURCES:

1. Electronic Waste Management Rules 2016, Govt. of India, available online at CPCB website.
2. MSW Management Rules 2016, Govt. of India, available online at CPCB website.
3. Hyperlink: https://onlinecourses.nptel.ac.in/noc18_ce07/preview

Subject Code: MST204 A	**Category**: Open Elective I
Subject Name: Introduction to Artifical Intelligence	**Semester**: Second
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Basic knowldege of Mathematics, Statics and Programming.	

COURSE OBJECTIVE:

Artificial Intelligence will define the next generation of software solutions. This computer science course provides an overview of AI, and explains how it can be used to build smart apps that help organizations be more efficient and enrich people's lives. It uses a mix of engaging lectures and hands-on activities to take first steps in the exciting field of AI.

COURSE OUTLINE:

Introduction, Machine Learning-The Foundation of AI, Text and Speech-Understanding Language, Computer Vision-Seeing the World Through AI, Bots-Conversation as a Platform, Next Steps.

LEARNING RESOURCES:

1. Introduction to Artificial Intelligence: G. Goswami; Paperback-2013.
2. Hyperlink: https://www.edx.org/course/introduction-artificial-intelligence-1

Subject Code: MST204 B	**Category**: Open Elective I
Subject Name: Block Chain Technology	**Semester**: Second
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Basic knowldege of Cryptocurrencies: Bitcoin and the Crypto Space.	

COURSE OBJECTIVE:

The course covers many key topics in the blockchain space. These include distributed systems and alternative consensus mechanisms, cryptoeconomic and proof-of-stake, fundamental applications of bitcoin and blockchain technology, including exploring enterprise blockchain implementations (JP Morgan's Quorum, Ripple, Tendermint, and HyperLedger), the challenges and solutions around scaling blockchain adoption, and the measures that the government is taking to regulate and control blockchain technology.

COURSE OUTLINE:

Distributed Systems and Alternative Consensus, Cryptoeconomics and Proof-of-Stake, Enterprise Blockchain: Real-World Applications, Scaling Blockchain: Cryptocurrencies for the Masses, Regulation and Anonymity, A Blockchain-Powered Future.

LEARNING RESOURCES:

1. Blockchain Technology Explained: The Ultimate Beginner's Guide About Blockchain Wallet, Mining, Bitcoin, Ethereum, Litecoin, Zcash, Monero, Ripple, Dash, IOTA And Smart Contracts: A. T. Norman; Paperback, 2017.
2. Hyperlink: https://www.edx.org/course/blockchain-advancing-decentralized-technology

Subject Code: MST204 C	**Category**: Open Elective I
Subject Name: Principles of Machine Learning	**Semester**: Second
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Knowledge of Data Science and Informatics	

COURSE OBJECTIVE:

Machine learning uses computers to run predictive models that learn from existing data in order to forecast future behaviors, outcomes, and trends. In this data science course, learner will be given clear explanations of machine learning theory combined with practical scenarios and hands-on experience building, validating, and deploying machine learning models. Learner will learn how to build and derive insights from these models using R, Python, and Azure Machine Learning.

COURSE OUTLINE:

Explore classification: Understand the operation of classifiers, Use logistic regression as a classifier, Understand the metrics used to evaluate classifiers, Classification with logistic regression taught using Azure Machine Learning; Regression in machine learning: Understand the operation of regression models, Use linear regression for prediction and forecasting, Understand the metrics used to evaluate regression models, Predicting bike demand with linear regression taught using Azure Machine Learning; How to improve supervised models: Process for feature selection, Understand the problems of over-parameterization and the curse of dimensionality, Use regularization on over-parameterized models, Methods of dimensionality reduction Apply cross validation to estimating model performance, Improving diabetes patient classification using Azure Machine Learning, Improving bike demand forecasting using Azure Machine Learning, Details on non-linear modeling: Understand how and when to use common supervised machine learning models Applying ML models to diabetes patient classification, Applying ML models to bike demand forecasting Clustering, Understand the principles of unsupervised learning models, Correctly apply and evaluate k-means clustering models, Correctly apply and evaluate hieratical clustering model, Cluster models with AML, R and Python; Recommender systems: Understand the operation of recommenders, Understand how to evaluate recommenders, Know how to use alternative to collaborative filtering for recommendations, Creating and evaluating recommendations.

LEARNING RESOURCES:

1. Machine Learning-The Art and Science of Algorithms that Make Sense of Data: Peter A. Flach, 2012.
2. Hyperlink: https://www.edx.org/course/principles-of-machine-learning

Subject Code: MST302 A	**Category**: Open Elective II
Subject Name: Micro and Nanofabrication	**Semester**: Third
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Basics in Physics and Chemistry	

COURSE OBJECTIVE:

Microfabrication and nanofabrication are the basis of manufacturing for nearly all modern miniaturized systems that are ubiquitously used in our daily life. Examples include; computer chips and integrated sensors for monitoring our environment, cars, mobile phones, medical devices and more.

Micro- and nanofabrication can be taught to students and professionals by textbooks and ex-cathedra lectures, but the real learning comes from seeing the manufacturing steps as they happen.

In this engineering course, we will go a step beyond classroom teaching to not only explain the basics of each fabrication step but also show how it’s done through video sequences and zooming into the equipment.

COURSE OUTLINE:

MEMS and cleanroom introduction: Basics of electromechanical systems (MEMS) and cleanroom fabrication. Chemical vapor deposition (CVD): Basic principles of CVD and cleanroom infrastructure used to run a CVD process.

Physical vapor deposition (PVD): Details of two main PVD methods; thermal evaporation and sputtering. Lithography: Details of two main resist patterning methods: optical and electron beam lithography.

Dry etching: Etching in a gas environment. Etching directionality and anisotropy. Simple rules for choosing dry etching processes for specific materials in a plasma reactor and provide theoretical concepts that characterize a plasma in a dry etching equipment.

Wet etching: Anisotropic wet etching of silicon substrates. Isotropic etching of silicon. Thin membrane microfabrication techniques using wet etching.

Inspection and metrology: Methods of inspection and metrology based on four technique categories: optical, mechanical, charged beam and electrical.

LEARNING RESOURCES:

1. Micro and Nanomanufacturing: Mark J. Jackson, Spinger, 2015.
2. Hyperlink: https://www.edx.org/course/micro-nanofabrication-mems-epflx-memsx-0

Subject Code: MST302 B	**Category**: Open Elective II
Subject Name: Internet of Things: Sensor and Devices	**Semester**: Third
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Nil	

COURSE OBJECTIVE:

The Internet of Things (IoT) is expanding at a rapid rate, and it is becoming increasingly important for professionals to understand what it is, how it works, and how to harness its power to improve your business.

This course is for practical learners who want to explore and interact with the IoT bridge between the cyber- and physical worlds, in order to create efficiencies or solve business problems.

In this course, students will learn about the 'things' that get connected in the Internet of Things to sense and interact with the real world environment-from something as simple as a smoke detector to a robotic arm in manufacturing. If we consider the IoT as giving the internet the ability to feel and respond, this course is about the devices that feel and the devices that respond. Stusents will learn IoT sensors, actuators and intermediary devices that connect things to the internet, as well as electronics and systems, both of which underpin how the Internet of Things works and what it is designed to do.

COURSE OUTLINE:

Generate IoT concepts and design IoT solutions. Map out the process for an IoT solution, and identify the sensors and other devices required. Evaluate different infrastructure components and network systems, and design the basic network for your IoT ideas. Apply software solutions for different systems and Big Data to concept designs, and appreciate how data is managed in the network. Identify and analyse IoT security and privacy risks, and concept design secure hardware and software. Produce a viable IoT concept design that solves a problem, is ready to prototype and test, and has an identified route to market.

LEARNING RESOURCES:

1. Internet of Things with Python: G. C. Hillar, Packt Publishing Limited.
2. Hyperlink: https://www.edx.org/micromasters/curtinx-internet-of-things-iot

Subject Code: MST302 C	**Category**: Open Elective II
Subject Name: Internet of Things: Sensing and Actuation from Devices	**Semester**: Third
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Nil	

COURSE OBJECTIVE:

In this course, student will learn to interface common sensors and actuators to the DragonBoard™ 410c hardware. They will then develop software to acquire sensory data, process the data and actuate stepper motors, LEDs, etc. for use in mobile-enabled products. Along the way, student will learn to apply both analog-to-digital and digital-to-analog conversion concepts.

COURSE OUTLINE:

Terminology/Cheat Sheet (Beginner), GPIO Programming, Amplifier Build, Stepper Motors, LED Block, Infrared Sensors, Bluetooth Remote, DragonBoard™ 410c Monitoring and Control.

LEARNING RESOURCES:

1. Getting Started with the Internet of Things: Connecting Sensors and Microcontrollers to the Cloud:Cuno Pfister, Oreilly & Associates INC.
2. Hyperlink: https://www.coursera.org/learn/internet-of-things-sensing-actuation

Sessional

Subject Code: MST181	**Category**: Mini Project
Subject Name: Mini Project with Seminar	**Semester**: First
L-T-P: 2-0-0	**Credit**: 2
Pre-Requisties: Nil	

Subject Code: MST281	**Category**: Mini Project
Subject Name: Mini Project with Seminar	**Semester**: Second
L-T-P: 2-0-0	**Credit**: 2
Pre-Requisties: Nil	

Mini Project would be to do some preliminary works that would lead to the detailed project work spanning over Semester III and IV. Related to the same, the Seminar would be based on literature review on some emerging areas related to this course and the preliminary works done on the mini project.

Seminar presentation would be made by an individual student, and a report would have to be submitted by each student separately.

Practical

Subject Code: MST191	**Category**: Laboratory-I
Subject Name: Characterization of Materials	**Semester**: First
L-T-P: 0-0-4	**Credit**: 2
Pre-Requisties:	

Laboratory experiments and exercises on:

1. Particle size analysis
2. Characterization of Materials through XRD, SEM, TEM, FTIR and UV-VIS.
3. Thermal analysis through TGA, DTA and DSC.
4. Determination of Microhardness and Abrasion Resistance.
5. Measurment of Thermal Expansion.

Subject Code: MST291	**Category**: Laboratory-II
Subject Name: Synthesis, Fabrication and Processing of Materials	**Semester**: Second
L-T-P: 0-0-4	**Credit**: 2
Pre-Requisties:	

Laboratory experiments and exercises on:

1. Powder preparation and Fabrication of Ceramic and Metallic Materials
2. Synthesis and Processing of Polymeric Materials
3. Metal forming operation

Subject Code: MST381	**Category**: Major Project
Subject Name: Dissertation-I (Progress)	**Semester**: Third
L-T-P: 0-0-20	**Credit**: 10
Pre-Requisties: Nil	

A Project Dissertation would be of two-semester duration and one project would be allotted to one student. The Progress of project dissertation up to the end of the Third Semester would be evaluated by the concerned supervisor and a panel of examiners through a seminar presentation on the progress of dissertation followed by viva voce. The Progress of project dissertation up to the end of the Third Semester would be presented by the student concerned and viva voce will be conducted by a panel of examiners.

Quality of the project is measured in terms of

- Very clear and concise objectives
- Very clear methodology, articulated using technical terms indicating all steps and tools
- Cites substantial current and good quality literature
- Clarity in design/setting up of experiment.
- Benchmarks used /Assumptions made
- Interpretation of results and justification thereof and validity of the results presented.
- Overall presentation of the report

Subject Code: MST481	**Category**: Major Project
Subject Name: Dissertation-II (Completion)	**Semester**: Fourth
L-T-P: 0-0-20	**Credit**: 10
Pre-Requisties: Nil	

Total output of the project work would have to be submitted in form of a bound thesis containing literature review, objective, details of work done, conclusion, reference, etc. The evaluation of the thesis will be done by a panel of examiners.
Final presentation and viva voce of the project will be based on the project thesis submitted to be conducted by a panel of examiners.

Quality of the project is measured in terms of

- Very clear and concise objectives
- Very clear methodology, articulated using technical terms indicating all steps and tools
- Cites substantial current and good quality literature
- Clarity in design/setting up of experiment.
- Benchmarks used / Assumptions made
- Interpretation of results and justification thereof and validity of the results presented.
- Overall presentation of the report

Mandatory Learning Course

Subject Code: MLC101	**Category**: Mandatory Learning Course
Subject Name: Research Methodology and IPR	**Semester**: First
L-T-P: 2-1-0	**Credit**: 2
Pre-Requisties: Nil	

Course Outcomes:

At the end of this course, students will be able to

- Understand research problem formulation.
- Analyze research related information
- Follow research ethics
- Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.
- Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasise the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular.
- Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.

Course Outline:

Unit 1: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Unit 2: Effective literature studies approaches, analysis Plagiarism, Research ethics,

Unit 3: Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Unit 4: Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents. Patenting under PCT.

Unit 5: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Unit 6: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Learning Resources:

- Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'
- Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
- Ranjit Kumar, 2 nd Edition, "Research Methodology: A Step by Step Guide for beginners"
- Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.
- Mayall, "Industrial Design", McGraw Hill, 1992.
- Niebel, "Product Design", McGraw Hill, 1974.
- Asimov, "Introduction to Design", Prentice Hall, 1962.
- Hyperlink:
  https://www.coursera.org/learn/research-methods
  https://www.edx.org/course/intellectual-property-law-policy-part-1-pennx-iplaw1x-0