M. Tech. (Two Years)

Course Curriculum and Syllabi

Specialization:

1. Materials Engineering
2. Manufacturing Technology

Department of Metallurgy and Materials Engineering

Indian Institute of Engineering Science and Technology Shibpur

भारतीय अभियांत्रिकी विज्ञान एवं प्रौद्योगिकी संस्थान, शिबपुर

ভারতীয় প্রকৌশল বিজ্ঞান এবং প্রযুক্তিবিদ্যা প্রতিষ্ঠান, শিবপুর

Howrah 711103, West Bengal, India

https://www.iiests.ac.in/IIEST/AcaUnitDetails/MME

Effective from July, 2021

FIRST SEMESTER

Table - 1

Specialization: 1. Materials Engineering, and 2. Manufacturing Technology

Sl. No	Paper	Credit
1	Paper-I (Dep. Core)	3
2	Paper-II (Dep. Core)	3
3	Paper-III (Dep. Core)	3
4	Paper-IV (Dep. Elec.)	3
5	Paper-V (Open Elec.)	3
	Theory Subtotal	**15**
6	Lab - I/ Mini Project - I	2
7	Lab - II/Mini Project - II	2
8	Lab - III/Mini Project - III	2
	Practical Subtotal	**6**
	Total Credit	**21**

Note:

1. Paper – I, II and III are compulsory subjects for the particular specialization.
2. Paper – IV, V are elective subjects, which are to be selected from the table below. A student may also opt for open electives offered by other departments for first semester M. Tech Students (subject to availability).
3. Lab – I, II, III are typically related to Paper – I, II and III. However, in some cases, if the Department feels, these may be related to Paper – IV and V also (for departmental electives only). In cases, where lab facility is not available, mini projects related to Paper – I/II/III may be offered.
4. The credits mentioned above are indicative and are as such to be followed. However, in cases, where it is essential to include a Tutorial or to increase the lab hours, credits may be increased to 4 (Theory)/3(Practical). In such cases, the total credit should not exceed 24.

a) Departmental Core Papers for the specialization (Paper – I, II, III)

Specialization: 1. Materials Engineering, and 2. Manufacturing Technology

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5101	Fundamentals of Materials	3	0	0	40	3	100
2	MM5102	Characterization of Materials	3	0	0	40	3	100
3	MM5103	Thermodynamics and Kinetics of Materials	3	0	0	40	3	100

b) *Departmental Elective* Papers for the specialization (Paper – IV)

***Specialization: 1.* Materials Engineering**

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5121	Functional Materials	3	0	0	30	3	100
2	MM5122	Composite Materials	3	0	0	40	3	100
3	MM5123	Surface Degradation and Protection	3	0	0	40	3	100

Specialization: 2. Manufacturing Technology

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5124	Iron and Steel Making	3	0	0	40	3	100
2	MM5125	Sustainable Materials Manufacturing	3	0	0	36	3	100
3	MM5126	Additive Manufacturing	3	0	0	40	3	100

b) *Open (non-departmental) Elective* Papers (Paper – V) offered by the Department of Metallurgy and Materials Engineering

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5161	Mechanical Behaviour of Engineering Materials	3	0	0	40	3	100
2	MM5162	Selection of Engineering Materials	3	0	0	40	3	100
3	MM5163	Joining of Materials	3	0	0	40	3	100

c) Departmental Labs for the specialization (Lab – I, II, III)

Specialization: 1. Materials Engineering, and 2. Manufacturing Technology

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5171	Fundamentals of Materials Lab.	0	0	3	33	2	100
2	MM5172	Characterization of Materials Lab.	0	0	3	30	2	100

d) Departmental Mini Projects for the specialization

Specialization: 1. Materials Engineering, and 2. Manufacturing Technology

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5173	Mini Project	0	0	3	30	2	100

Note: In cases, where Mini Project if offered, the related Paper (Paper – I, II or III) should be mentioned.

SECOND SEMESTER

Table – 2

***Specialization:* 1. Materials Engineering, and 2. Manufacturing Technology**

Sl. No	Paper	Credit
1	Paper – VI (Dep. Core)	3
2	Paper – VII (Dep. Core)	3
3	Paper – VIII (Dep. Core)	3
4	Paper-IX (Dep. Elec)	3
5	Paper-X (Open Elec.)	3
	Theory Subtotal	**15**
6	M. Tech Project Part – I (Term Paper)	4
7	Term Paper Seminar & Viva-voce	2
8	**Practical Subtotal**	**6**
	Total Credit	**21**

Note:

1. Paper – VI, VII and VIII are compulsory subjects for the particular specialization.
2. Paper – IX, X are elective subjects, which are to be selected from the table below. A student may also opt for open electives offered by other departments for second semester M. Tech Students (subject to availability).
3. For M. Tech Thesis Part – I (Term Paper), the student will work under the guidance of the Supervisor(s) from the beginning of the second semester, and submit the Term Paper (literature review and objective and scope of the broad area of M. Tech thesis work). Submission will be followed by a seminar and viva-voce.
4. The credits mentioned above are indicative and are as such to be followed. However, in cases, where it is essential to include a Tutorial credits may be increased to 4 (Theory). In such cases, the total credit should not exceed 23.

a) Departmental Core Papers for the specialization (Paper – VI, VII, VIII)

Specialization: 1. Materials Engineering, and 2. Manufacturing Technology

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5201	Manufacturing Processes	3	0	0	40	3	100
2	MM5202	Mechanical Behaviour of Materials	3	0	0	40	3	100
3	MM5203	Multiscale Materials Modelling	3	0	0	40	3	100

b) Departmental Elective Papers for the specialization (Paper – IX)

***Specialization: 1.* Materials Engineering**

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5221	Design and selection of Materials	3	0	0	40	3	100
2	MM5222	Energy Materials	3	0	0	40	3	100
3	MM5223	Surface Treatment and Modification	3	0	0	38	3	100

Specialization: 2. Manufacturing Technology

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5224	Joining Technology	3	0	0	40	3	100
2	MM5225	Engineering Tribology	3	0	0	40	3	100
3	MM5226	Microsystem Technology	3	0	0	40	3	100

b) *Open (non-departmental) Elective* Papers (Paper – X) offered by the Department of Metallurgy and Materials Engineering

Sl. No	Subject code	Subject Name	Class Load/Week			Total load (h)	Credit	Marks
			L	T	P			
1	MM5261	Nanostructures and Nanomaterials	3	0	0	38	3	100
3	MM5262	Biomedical Materials and Devices	3	0	0	38	3	100
4	MM5263	Non-destructive Testing	3	0	0	40	3	100

c) M. Tech Project Part – I

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	MM5291	M. Tech thesis Part – I (Term Paper)	8	4	200
2	MM5292	Term Paper Seminar & Viva-voce		2	100

THIRD SEMESTER

Sl. No	Paper	Credit
1	M. Tech Thesis Part – II (Progress Report)	12
2	Progress Report Seminar & Viva-voce	6
	Total Credit	**18**

Note:

1. *For M. Tech Thesis Part – II (Progress Report), the student will submit the details of work done for the M. tech Thesis during the third semester, and findings (if any). Submission will be followed by a seminar and viva-voce.*

M. Tech Project Part – II

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	MM6191	M. Tech Thesis Part – II *(Progress Report)*	24	12	300
2	MM6192	Progress Report Seminar & Viva-voce		6	100

FOURTH SEMESTER

Sl. No	Paper	Credit
1	**M. Tech Final thesis**	**22**
2	**Thesis Seminar & Viva-voce**	**8**
	Total Credit	**30**

Note:

1. *For M. Tech Final thesis, the student will compile the entire work done for the M. Tech Project, along with the findings, in the form of a Thesis and submit at the end of the semester. Thesis submission will be followed by a Thesis seminar and viva-voce.*

M. Tech Project Part – III

Sl. No	Subject code	Subject Name	Total load (h)	Credit	Marks
1	MM6291	M. Tech Final thesis	30	22	400
2	MM6292	Thesis Seminar& Viva-voce		8	200

Total Credit: 21 + 21 + 18 + 30 = 90

Note on Subject Code:

XX: Department Code (AE, CE, ME, etc.); YY: Year(Y)-Semester(Y) (51, 52, 61, 62, etc.);
ZZ: Subject Code (01 to 49 for Theory subjects, 50-99 for practical subjects.
Example: AE5124 [Aerospace Engineering, Fifth Year (PG), First Semester, 24 subject code)

Course Code	MM5101	*Course Name*	Fundamentals of Materials	*Course Category*	Core Theory	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*			NIL	

Module	Syllabus	Duration(h)
Module-I	**Introduction** Classification of engineering materials; Elements of crystallography, Bravais lattice & Miller indices, Atomic packing; Crystal imperfections	06
Module-II	**Review of Phase Transformation** Phase rule, Types and construction of phase diagrams, Free energy-composition diagrams, Lever Rule, Introduction to ternary system	06
Module - III	**Fe-C system** steel and cast iron microstructures with phase relations	06
Module -1V	**Solidification** Homogeneous & Heterogeneous nucleation, Growth; Dendritic solidification; Segregation	06
Module-V	**Diffusion** Diffusion laws, Kirkendall effect, activation energy, uphill diffusion *etc.*	04
Module -VI	**Solid-state phase transformation** Nucleation and Growth kinetics, T-T-T and C-C-T diagrams	02
Module - VII	**Diffusional and diffusion less phase transformation processes** Polymorphic transformation, pearlite, bainite and martensite transformations, massive transformation, order-disorder transformation, precipitation, recrystallization	08
	Total contact hours	**40**

Learning Resources	**Materials Science and Engineering**: W.F. Smith, J. Hashemi and R Prakash, McGraw Hill **The Science and Engineering of Materials**, D.R. Asheland, Springer Science **Fundamentals of Materials Science and Engineering**: W.D. Callister, Jr, John Wiley & Sons, Inc. **Materials Science and Engineering - A First Course**, V. Raghavan, PHI

Course Code	MM5102	*Course Name*	Characterization of Materials	*Course Category*	Core Theory	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*			*NIL*	

Module	Syllabus	Duration(h)
Module-I	**Introduction** Introduction to Advanced material characterization techniques	01
Module-II	**X-ray diffraction pattern analysis** Determination of crystal structure, crystal size, lattice parameter, quantitative phase analysis and defect analysis.	08
Module - III	**Advanced optical Microscopy** Interference, Phase contrast, polarized light and near field scanning optical microscopy	04
Module -1V	**Electron Microscopes** Scanning Electron Microscopes and Transmission Electron microscopes, Electron diffraction and diffraction pattern analysis	10
Module-V	**Scanning probe Microscope** Scanning tunneling microscope, Atomic force microscope, Magnetic force microscope	05
Module VI	**Spectroscopy** Principle and application of Energy dispersive spectroscopy, Auger electron spectroscopy, X ray photo electron spectroscopy, x-ray fluorescence spectroscopy, Raman spectroscopy. Fourirer transform Infrared spectroscopy	08
Module-VII	**Thermal Characterization techniques** DSC, DTA-TGA, principles and applications	04
	Total contact hours	**40**

Learning Resources	**Elements of X-ray diffraction:** B.D Cullity **Materials Characterization: Introduction to Microscopic and Spectroscopic Methods,** Yang Leng **Transmission Electron Microscopy,** David B Williams, and C. Barry Carter **Scanning Electron Microscopy**, Garrett Thomas

Course Code	MM5103	*Course Name*	Thermodynamics and Kinetics of Materials	*Course Category*	Core Theory	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*		NIL		

Module	Syllabus	Duration(h)
Module-I	Basics of statistical thermodynamics and derivation of thermodynamics quantities	05
Module-II	Laws of thermodynamics, activity, equilibrium constant, application to metallurgical systems.	08
Module-III	Thermodynamics of solutions and phase equilibria.	10
Module-IV	Thermodynamics of electrochemical cells and degradation phenomena.	04
Module-V	Thermodynamics of surfaces, interphases and defects.	04
Module-VI	Basic kinetic laws, rate constants and rate limiting steps.	04
Module-VII	Experimental and theoretical techniques in thermodynamics of materials.	05
	Total contact hours	**40**

Learning Resources	**Statistical mechanics: A survival guide**, A. M. Glazer and J. S. Wark, Oxford University Press. **Textbook of Materials and Metallurgical Thermodynamics**, Ahindra Ghosh, PHI Eastern Economy edition. **Introduction to the Thermodynamics of Materials**, David R. Gaskell, Taylor and Francis. **A Textbook of Metallurgical Kinetics**, Sudipto Ghosh and Ahindra Ghosh, PHI Eastern Economy edition. S.K. Bose and Sanat Roy, IIM, Springer Verlag Darken and Gurry

Course Code	MM5121	*Course Name*	Functional Materials	*Course Category*	Departmental Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*			*NIL*	

Module	Syllabus	Duration(h)
Module-I	**Overview of functional Materials, structure properties and their classification.**	02
Module-II	**Ferroelectric, Piezoelectric and Piezoelectric Materials:** Perovskite structure and spontaneous polarization, relationship of ferroelectrics and piezoelectric to crystal symmetry, Devices based on piezoelectric property, Piezoelectric composites, Pyroelectric materials and devices	08
Module-III	**Shape Memory Alloys:** Structural Thermo-elastic Phase Transition in Shape Memory Alloys, Dependency Between Microstructure and Elastic Behavior of SMA, Discontinuous Change of Physical Properties—Martensitic Phase Transition, Different Approaches to Describe the Shape-Memory Effect, Quantitative Models for Shape Memory Alloys	06
Module- IV	**Magnetorheological and Electrorheological Fluids:** Viscoelastic Properties and Basic Rheology, Some Rheological Models, Understanding the Microscopic Structure of ERF and MRF, ER- and MR-effect Explained by the Interaction of Induced Dipoles, Applications—Switchable Fluid Acting as a Valve	06
Module-V	**Nanostructured functional materials: S**emiconducting oxide films, Metallic nanoparticles, Carbon-based nanostructured materials for energy storage and conversion	06
Module-VI	**Functionally graded materials and their applications.**	04
	Total contact hours	**32**

Learning Resources	**The Physics of Multifunctional Materials Concepts, Materials, Applications**, Martin Gurka **Nanostructure Multifunctional Materials** by Esteban A. Franceschini

Course Code	MM5122	**Course Name**	Composite Materials	**Course Category**	Departmental Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		**Pre-requisite Courses**		NIL		

Module	Syllabus	Duration(h)
Module-I	**Introduction** Definitions of composites, reinforcements and matrices, Types of reinforcements, Types of matrices, Types of composites, Carbon Fibre composites, Properties of composites in comparison with standard materials, Applications of metal, ceramic and polymer matrix composites.	8
Module-II	**Manufacturing methods** Hand and spray lay - up, injection molding, resin transfer moulding, filament winding, pultrusion, centrifugal casting and prepregs. Characterization of systems: carbon fibre/epoxy, glass fibre/polyester etc.	6
Module-III	**Design of composites** In-situ and ex-situ composites; Interfaces between reinforcements and matrices in composites; Bonding Mechanisms, Bond Strength, Interfacial Toughness.	6
Module- IV	**Mechanical Properties** Stiffness and Strength, Geometrical aspects – volume and weight fraction. Unidirectional continuous fibre, discontinuous fibers, Short fiber systems, woven reinforcements – Mechanical Testing: Determination of stiffness and strengths of unidirectional composites; tension, compression, flexure and shear.	8
Module-V	**Laminates** Plate Stiffness and Compliance, Assumptions, Strains, Stress Resultants, Plate Stiffness and Compliance, Computation of Stresses, Types of Laminates -, Symmetric Laminates, Antisymmetric Laminate, Balanced Laminate, Quasi-isotropic Laminates, Cross-ply Laminate, Angle-ply Laminate. Orthotropic Laminate, Laminate Moduli, Hygrothermal Stresses	8
Module-VI	**Joining Methods and Failure Theories** Joining – Advantages and disadvantages of adhesive and mechanically fastened joints. Typical bond strengths and test procedures.	4
	Total contact hours	**40**

Learning Resources	1. F. L. Matthews and R. D. Rawlings: **Composite Materials: Engineering and Science**: Woodhead Publishing Limited. 2. R. M. Jones**, Mechanics of Composite Materials**, CRC Press 3. M. Mukhopadhyay, **Mechanics of Composite Materials**, University Press 4. I. S. Daniel and Ori Ishai, **Engineering Mechanics of Composite Material**, Oxford University Press 5. K. K. Chawla: **Composite Materials: Science and Engineering**: Springer

Course Code	MM5123	Course Name	Surface Degradation and Protection	Course Category	Departmental Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		Pre-requisite Courses		NIL		

Module	Syllabus	Duration(h)
Module-I	An introduction: Technical and economic aspect of the study of surface degradation.	2
Module-II	Electrochemical principles of corrosion cell; exchange current density; electrode potential and standard cells, EMF series and galvanic series— their applications, application of Faraday's law in corrosion.	4
Module-III	Thermodynamics of corrosion: Pourbaix diagram constriction and application, Polarization: types, factors involved, effect on degradation rate; Passivation: factor involved, effect on degradation rate	8
Module-IV	Mixed Potential theory; Tafel equation, construction and interpretation of Polarization diagrams.	6
Module-V	Different forms of degradation -uniform attack, galvanic, crevice, pitting, intergranular, selective leaching, erosion corrosion and stress corrosion cracking, Hydrogen effect, corrosion fatigue and microbes induced corrosion. Liquid metal embrittlement-their characteristic features, causes and remedial measures. Surfce degradation testing methods and interpretation of results.	8
Module-VI	High temperature surface degradation — Mechanism to formation films on the surface, Ellingham diagrams, Pilling-Bedworth ratio, and their effects on kinetics, oxide defect structures, rate laws, types of oxidation, materials for use at elevated temperatures.	6
Module-VII	Degradation by wear of materials; its characteristics, wear testing and measurement, Wear-resistant materials	3
Module-VII	Preventive measurement of surface degradation: material selection and design aspects; control of environment including inhibitors, cathodic and anodic protection, coatings and other surface protection techniques of metals and alloys.	4
	Total contact hours	**40**

Learning Resources	**Principles and Prevention of Corrosion**, Denny A. Jones, Prentice-Hall **Corrosion Engineering**, 3rd Ed., Mars G. Fontana, McGraw-Hill, Singapore. **Corrosion and its Control**, 3rd Ed., H.H. Uhlig and R.W. Revie, John Wiley, Singapore. **Stress corrosion cracking : Theory and Practice**, V S Raja and T Shoji (eds), Woodhaed Publishing Limited, Oxford. **Corrosion Failures: Theory, Case Studies and Solutions**, K.E. Perumal and V.S. Raja; John Wiley & Sons, USA 2 A.S. Khanna, **Introduction to High Temperature Oxidation and Corrosion**, ASM International, Materials Park, Ohio

Course Code	**MM5124**	**Course Name**	**Iron and Steel Making**	**Course Category**	**Departmental Elective**	**L**	**T**	**P**
						3	**0**	**0**
Course Offering Department		**Metallurgy and Materials Engineering**		**Pre-requisite Courses**			**NIL**	

Module	**Syllabus**	**Duration(h)**
Module-I	Up gradation of raw materials: Washing of Ore & Coal; Advances in Agglomeration of Iron Ores – process control and current innovations. Characteristics of suitable Raw Materials.	03
Module-II	Blast furnace (BF) Iron Making- Design Features of BF and supporting units, viz. Coke Ovens, Stoves, Gas Cleaning Systems. Recent Trends in Iron Making; Gas – Solid and Slag Metal Reactions; Sponge Iron Making.	04
Module-III	Reduction Mechanism and Equilibrium in Carbon-Oxygen System; Slag formation - Chemistry and Characteristics; Reserve Zones, Cohesive Zone and their Importance.	04
Module- IV	Modern trends to Minimize Coke Rate and Emissions; Injection techniques; Blast furnace (BF) Irregularities and Remedies. Treatment of Slag and Outgoing Gas.	04
Module-V	Alternate routes of Iron making - Direct reduced iron (DRI); Gas based and Coal-Based DRI; Hot Briquetted Iron (HBI); Problems and prospects of DRI in India.	04
Module-VI	Steel making: Principles of Refining, Steel making in Basic Oxygen Blown Converters, Kinetics of Reactions and Lance Design.	04
Module-VII	Arc furnace Steel Making - Production of Alloy Steels; Induction Furnace Steel Making: Use of DRI in Steel Making.	03
Module-VIII	Secondary Steel Making - Quality, Continuous Steel Making; Continuous Casting; Vacuum Degassing and Electro Slag Re-melting de-oxidation and de-sulphurization; Vacuum techniques – Re-melting and Refining; Injection Metallurgy.	04
Module-IX	Inclusion removal and its modification. Casting of ingots and Continuous Casting. Defects and Remedies.	04
Module-X	Energy and Environmental aspects in Steel Making, concept of Zero CO_2 Emission.	02
Module-XI	Latest Developments in Iron and Steel Making Processes.	04
	Total contact hours	**40**

Learning Resources	**An Introduction to Modern Iron Making** - R. H. Tupkary **An Introduction to Modern Steel Making** - R. H. Tupkary **Principles of Blast Furnace Ironmaking: Theory and Practice** - A. K. Biswas **Ironmaking and Steelmaking: Theory and Practice** - Ahindra Ghosh and Amit Chatterjee A.K. Chakrabarty, Prentice-Hall **Steel Making--**A.K. Chakrabarti (Prentice Hall of India) **Principles of Metallurgical Thermodynamics --** S.K. Bose and S.K. Roy (Springer).

Course Code	MM5125	Course Name	Sustainable Materials Manufacturing	Course Category	Departmental Elective	L	T	P
						3	0	0
Course Offering Department	Metallurgy and Materials Engineering			Pre-requisite Courses		NIL		

Module	Syllabus	Duration(h)
Module-1	**Introduction to the Course** A brief history of manufacturing, commerce and sustainability	2
Module-2	**Basic concepts** on of sustainability, manufacturing, operations, processes, practices, Resources in manufacturing. Supply chain operations	6
Module-3	**Carbon Footprint of Materials Manufacturing** CO2 and greenhouse gases emissions in the manufacturing sector. Major CO2 emitting industries and calculation of carbon-footprint associated with manufacturing industries (emphasis on Steel and Aluminium industry). Alternative approaches for metal production with limited and/or reduced carbon footprint.	6
Module-4	**Design of Materials and Manufacturing for Resource Efficiency** Issue of limited materials resources, Socio-economic issues related to mineral resources. Concepts of optimization, numerical optimization through simulation.*Case studies* related to dependence on Li for battery materials and rare-earth for magnetic and structural materials.	6
Module-5	**Life Cycle Analysis** Basic steps on Life Cycle Analysis-Goal definition, Analysis, Assessment and Interpretation. *Case studies* on Life Cycle Analysis on Wind Farm Materials, Microelectronics Materials, etc.	6
Module-6	**Modern approaches for Sustainable Manufacturing** Green manufacturing techniques: dry and near-dry machining, edible oil based cutting fluids, cryogenic machining for eco-efficiency. Implementation of lean methods. Simulation for sustainable manufacturing, Building a smart green factory: simulation techniques.	6
Module-7	**Recycling of Materials** Different types of materials environmental impact during different parts of their life-cycle including waste management and materials recycling. Toxicological aspects of material production and usage.	4
	Total	**36**

Learning resources	**Sustainable Manufacturing: Concepts, Tools, Methods and Case Studies**, S. Vinodh, CRC Press, 2020 **Sustainable Manufacturing and Remanufacturing Management: Process Planning, Optimization and Applications**, W. Li, S. Wang, Springer, 2017 **Sustainable Manufacturing**, K. Salonitis, K. Gupta, Elsevier, 2021 **Sustainability in Manufacturing Recovery of Resources in Product and Material Cycles**; G. Seliger, Springer, 2007 **Strategies for improving sustainability of structural materials,** D. Raabe, C. CemTasan, E. A. Olivetti, Nature, 575 (2019) 64-74.

Course Code	MM5123	*Course Name*	**Additive Manufacturing**	*Course Category*	Departmental Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*			*NIL*	

Module	Syllabus	Duration(h)
Module-I	**Introduction to Additive Manufacturing (AM)** Introduction, evolution of AM, distinction between AM & traditional manufacturing processes, advantages of AM.	07
Module-II	**Classification of AM** Prototyping, Rapid Manufacturing: indirect manufacturing, extrusion-based, powder bed fusion, directed energy deposition, laser AM processes, classification, processing philosophy, and metallurgical mechanisms, electron beam technology, plasma arc, other sources	14
Module-III	**Materials science for AM** Atomic structure and bonding, metal and ceramic powders, compaction and sintering of powders, composites, role of solidification rate, evolution of non-equilibrium structure, microstructural studies, structure property relationship.	07
Module- IV	**Guidelines for Process Selection** Introduction, selection methods and challenges for a part, process planning and control, selection of AM technologies using decision methods	07
Module-V	**Post Processing of AM Parts** Support material removal, improvement of surface texture, accuracy and aesthetics, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques, industry 4.0 and digital twins.	05
	Total contact hours	**40**

Learning Resources	Reference texts: 1. Ian Gibson, David W Rosen, Brent Stucker., "**Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing**", 2nd Edition, Springer, 2015. 2. Patri K. Venuvinod and Weiyin Ma, "**Rapid Prototyping: Laser-based and Other Technologies**", Springer, 2004. 3. Chua Chee Kai, Leong Kah Fai, "**3D Printing and Additive Manufacturing: Principles &Applications**", 4th Edition, World Scientific, 2015. 4. D.T. Pham, S.S. Dimov, **Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling**, Springer 2001. 5. Rafiq Noorani, **Rapid Prototyping: Principles and Applications in Manufacturing**, John Wiley & Sons, 2006.

Course Code	MM5161	*Course Name*	Mechanical Behaviour of Engineering Materials	*Course Category*	Open Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*		NIL		

Module	Syllabus	Duration(h)
Module-I	**Introduction to deformation and failure** Concept of stresses and strains; Engineering and true stresses and strains; Different types of loading and temperatures encountered in engineering applications; Mechanical behaviour and failure of metals, alloys, ceramics, polymer and composites materials	08
Module-II	**Elastic deformation** State of stress and strain; Principal stress and strain; elastic stress-strain relation; Elastic behaviour of engineering materials	06
Module-III	**Plastic deformation** Hydrostatic and deviatoric stress; Octahedral stress; Effective stress and strain; Yield criteria; Mohr circle; Plastic stress-strain relation;	06
Module- IV	**Mechanisms of plastic deformation** Crystal defects; Dislocation; Geometrical and statistical dislocations; Dislocation multiplication; Dislocation reactions; Slip and twinning; Critical resolved shear stress; Strain hardening; Hall-Petch relationship	08
Module-V	**Fracture** Fracture in engineering materials; Modes and mechanisms of fractures; Linear elastic fracture mechanisms; Elastic-plastic fracture mechanisms; Measurement of fracture toughness	08
Module-VI	**Fatigue** Types of dynamic loading; S-N curves; Classification of fatigue; Fatigue of engineering materials; Mechanisms of fatigue failure; Fatigue life prediction	06
Module-VII	**Creep** Time dependent deformation; Different stages of creep; Creep and stress rupture; Creep mechanisms and maps; Design of materials for high temperature applications	06
	Total contact hours	**40**

Learning Resources	**Deformation and Fracture Mechanics of Engineering Materials**: R.W. Hertzberg, John Wiley and Sons **Mechanical Metallurgy**, G.E. Dieter, McGraw-Hill **Mechanical Behavior of Materials**: M.A. Meyers, K K. Chawla, Cambridge Press **Fatigue of Materials**: S. Suresh, Cambridge Univ. Press **Mechanical Behavior of Materials**: N. E. Dowling, Prentice-Hall. **Fracture Mechanics: Fundamentals and Applications**: T.L. Anderson, CRC Press

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<tr><td rowspan="2">Course Code</td><td rowspan="2">MM5162</td><td rowspan="2">Course Name</td><td rowspan="2">Selection of Engineering Materials</td><td rowspan="2">Course Category</td><td rowspan="2">Open Elective</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>3</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Course Offering Department</td><td colspan="2">Metallurgy and Materials Engineering</td><td colspan="3">Pre-requisite Courses</td><td colspan="2">NIL</td></tr>
</table>

Module	**Syllabus**	**Duration(h)**
Module-I	Material Dependence (Introduction): Materials Brief History, Classification of materials, Materials and Environment, Materials – Energy carbon triangle, Material lifecycle	4
Module-II	Material Properties: Material for mechanical properties (Material for static strength, toughness, stiffness, fatigue and Creep resistance)	8
Module -III	Material for surface durability (Material for corrosion and wear resistance)	6
Module-IV	Material Selection strategy: Principle of material selection, selection criteria and material property charts, trade of methods (Resolving conflicting objectives), Modulus- density charts, The Strength-Density chart, The Modulus-Embodied energy and Strength-Embodied energy charts, The Modulus-Carbon footprint and Strength-Carbon footprint charts, The Thermal conductivity-Thermal diffusivity chart	10
Module- V	Case Studies: Material for drink containers (e.g., Carbonated drinks), Materials for building, Materials for heating and cooling (Solar heating, kilns, Cyclic heating), Materials for transport (Crash barrier, light weight structures, material substitution for eco-efficient design)	10
Module-VI	Renewable materials: Mineral based material, Vegetable-derived materials — (wood and wood-like materials, fibres), Bio-derived materials (Biopolymers, Bio-composites)	2
	Total contact hours	**40**

Learning Resources	1. Ashby M.F., **Materials and the Environment** 2. F. A. A. Crane, J. A. Charles, **Selection and Use of Engineering Materials** 3. Ashby M.F., Shercliff H., Cebon D., **Materials: Engineering, Science, Processing and Design**

Course Code	MM5163	*Course Name*	Joining of Materials	*Course Category*	Open Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*			*NIL*	

Module	Syllabus	Duration(h)
Module-I	Introduction to joining, mechanical joining, threaded and unthreaded joints, calculation of stresses. Adhesive bonding, mechanism of adhesive bonding	8
Module-II	Welding: classifications in welding, Arc welding, resistance welding, Oxy-fuel welding, Laser-beam welding, Electron beam welding, Diffusion welding, Friction welding, Ultrasonic welding	10
Module-III	Brazing: Torch Brazing, Furnace Brazing, Dip Brazing, Induction Brazing, Resistance Brazing, Microwave Brazing, Choice of Filler material	5
Module- IV	Soldering: Different types of soldering, Metallurgy of soldering alloys, Lead-tin and antimony binary and ternary alloy	5
Module-V	Heat transfer during Welding, Microstructural changes due to Welding, Brazing and Soldering	5
Module-VI	Joining in Ceramics, Glasses and Polymers	7
	Total contact hours	**40**

Learning Resources	1. **Joining of Materials and Structures** by Robert W. Messler, Jr., Elsevier. 2. **Welding Processes and Technology** by Parmar R.S., Khanna Publishers, Delhi. **3. Metallurgy of Welding** by J. F. Lancaster, Woodhead Publishing 4. **Principles of Welding Technology**, by L. M. Gourd, Viva Books, New Delhi.

Course Code	MM5171	Course Name	Fundamentals of Materials Lab.	Course Category	Laboratory I	L	T	P
						0	0	2
Course Offering Department		Metallurgy and Materials Engineering		Requisite Courses			MM0901	

Module	Syllabus	Duration(h)
Lab. I	***Metallographic Sample Preparation -I:*** Sectioning, Mounting, Grinding, Polishing,	03
Lab. I	***Metallographic Sample Preparation -II:*** Fine polishing, Electro-polishing, Etching	03
Lab. III	**Optical Microscope and microstructural characterization**	03
Lab. IV	**Microstructure of ferrous materials**	03
Lab. V	**Microstructures of non-ferrous materials**	03
Lab. VI	**Image Analyses**	03
Lab. VII	**Bulk Hardness Testing I**	03
Lab. VIII	**Bulk Hardness Testing II**	03
Lab. IX	**Microhardness Testing**	03
Lab. X	**Impact Testing**	03
Lab. XI	**Tensile Testing**	03
	Total contact hours	**33**

Learning Resources	**Metallographic Specimen Preparation: Optical and Electron Microscopy**, J. L. McCall, Springer **Metallography Principles and Practice**: G. F. Vander Voort, ASM International **Testing of Metallic Materials:** A. V. K. Suryanarayana, PHI Pub.

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">MM5172</td><td rowspan="2">Course Name</td><td rowspan="2">Characterization of Materials Lab.</td><td rowspan="2">Course Category</td><td rowspan="2">Laboratory II</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>0</td><td>0</td><td>2</td></tr>
<tr><td colspan="2">Course Offering Department</td><td colspan="2">Metallurgy and Materials Engineering</td><td colspan="3">Requisite Courses</td><td colspan="2">MM0902</td></tr>
</table>

Module	**Syllabus**	**Duration(h)**
Lab. I & II	**X-ray diffraction pattern analysis**: Crystal structure, size and precise lattice parameter determination.	06
Lab. III & IV	**Optical microscopy**: Sample preparation and microstructural characterization.	09
Lab. V & VI	**Electron Microscopes**: Scanning Electron Microscopes and Transmission Electron microscopes, Image and diffraction pattern analysis	06
Lab. VII & VIII	**Scanning probe Microscope**: Scanning tunnelling microscope, Atomic force microscope, Magnetic force microscope demonstration	09
Lab. IX & X	**Thermal Characterization techniques**: DSC, DTA-TGA demonstration and analysis	06
	Total contact hours	**30**

Learning Resources	B.D Cullity: **Elements of X-ray diffraction** Yang Leng: **Materials Characterization: Introduction to Microscopic and Spectroscopic Methods** David B Williams, C. Barry Carter, **Transmission Electron Microscopy**

Course Code	MM5173	*Course Name*	Mini Project	*Course Category*	*Laboratory II*	L	T	P
						0	0	3
Course Offering Department		Metallurgy and Materials Engineering		*Pre-Requisite Courses*			*NIL*	

Module	Syllabus	Duration(h)
	Course structure to be decided by the concerned faculty member on the basis of the topic selected by the student.	
	Total contact hours	**30**

Course Code	MM5201	*Course Name*	Manufacturing Processes	*Course Category*	Core Theory	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*		NIL		

Module	Syllabus	Duration(h)
Module-I	**Introduction to manufacturing processes** Product design process; Computer-aided design; Selection of materials and manufacturing processes; Inter-relation amongst chemistry-processing-property-performance; Computer Integrated Manufacturing; Quality assurance; Total Quality Management; Green manufacturing	02
Module-II	**Metal Casting Processes** Fundamental of metal casting; Cast structure; Casting processes; Sand casting; Permanent mold casting; Rapid solidification; Casting defects	05
Module-III	**Forming and Shaping Processes** Fundamental of metal forming; Hot, warm and cold working; Forming and shaping practices - forging, rolling, extrusion, wire drawing, sheet metal forming; Equipment; Die materials and design; Defects; Residual stresses; Economics of forming	05
Module-IV	**Machining Processes** Mechanics of cutting; Chip formation; Cutting force and power; Turning process; Laths and their operations; Tool materials; Tool wear and failure; Tool life; Machinability	04
Module-V	**Joining Processes** Fundamental of joining; Classification of joining; Fusion welding - Oxyfuel Gas welding, Arc Welding, TIG, MIG; Solid-state joining- Diffusion bonding, Friction stir welding, Resistance welding; Weldability; Carbon equivalent; Inspection, quality control and testing;	04
Module-VI	**Processing of non-metals** **Glass working:** Raw materials, melting, shaping, heat treatment and finishing. **Plastic shaping:** Extrusion, production of sheet and film, production of fiber and filament, coating processes, injection molding, polymer foam processing and forming. **Rubber processing:** Rubber processing and shaping, manufacturing of tires and other rubber products. **Case studies**	06
Module-VII	**Non-equilibrium processing** **Thermodynamics and kinetics of metastable phase formation** **Rapid solidification:** methods; constitution and microstructure formation; properties, performance, and applications of rapidly solidified materials **Mechanical alloying:** Process; mechanism; consolidation; synthesis of non-equilibrium phases; applications **Chemical Vapor Deposition:** Gas-phase transport and reactivity; Solid phase formation; applications **Physical Vapor Deposition:** Deposition methods; Influence of energy on coating, Applications, future trends **Case studies**	08
Module-VIII	**Processing of Integrated Circuit** **Clean room and Process sequence** **Silicon processing:** raw material; MGS to EGS conversion; Crystal growth, cleaning **Lithography:** Photolithography and other lithography techniques **Oxidation:** Thermal oxidation, kinetics of oxidation, different types of oxidation **Doping:** Diffusion, Ion-implantation **Metallization** **Testing and packaging** **Case studies**	06
	Total contact hours	**40**

Learning Resources	**Manufacturing Engineering and Technology**, S Kalpakjian and S Schmid, 7th Ed., Pearson **Fundamentals of Modern Manufacturing**, Mikell P. Groover **Materials and Processes in Manufacturing**, DeGarmo, Black, and Kohser, Wiley & Sons, Inc, **Non-equilibrium processing of materials**, C. Suryanarayana **Device Electronics for Integrated Circuit**, R. S. Muller, T. I. Kamins and M. Cha

Course Code	MM5202	*Course Name*	Mechanical Behaviour of Materials	*Course Category*	Core Theory	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*			NIL	

Module	Syllabus	Duration(h)
Module-I	**Review of Basic Mathematics** Vectors and tensors, dot and cross products; rotation of vectors and tensors; calculation of eigenvalues and eigenvectors; introduction to programming using MATLAB	4
Module-II	**Theory of Elasticity** Definition of stress and strain in 2-dimensions and in 3-dimensions; Mohr's circle of stress in two-dimensions; hydrostatic and deviatoric components of stress and strain; conversion of stresses to strains and vice-versa in elastic regime; Definition of elastic stiffness tensor for anisotropic materials; Micromechanics of linear elastic composites	8
Module-III	**Theory of Plasticity** Yield criteria in metals, ceramics and polymers; yield locus in 2D and in 3D; Octahedral stresses and strains; Levi-Mises and Prandtl-Reuss equations; yielding of anisotropic materials;	8
Module- IV	**Microstructural Aspects of Plasticity** Plasticity in single crystals; calculation of critical resolved shear stress; use of stereographic projection; Dislocations, interaction of dislocations; Twins; Stacking Faults	8
Module-V	**Strengthening Mechanisms** Strain hardening, grain boundary strengthening, solid solution strengthening, second phase strengthening	4
Module-VI	**Fracture** Fracture mechanisms, linear elastic fracture mechanics, toughening mechanisms	8
	Total contact hours	**40**

Learning Resources	**Mechanical Behaviour of Materials**, T. H. Courtney, Waveland Press **Deformation and Fracture Mechanics of Engineering Materials**: R.W. Hertzberg, John Wiley and Sons **Mechanical Metallurgy**, G.E. Dieter, McGraw-Hill **Mechanical Behavior of Materials**: M.A. Meyers, K K. Chawla, Cambridge Press **Physical Properties of Crystals: Their Representation by Tensors and Matrices**, J. Nye, Clarendon Press **Getting Started with MATLAB**, R. Pratap, Oxford University Press

Course Code	MM5203	Course Name	Multiscale Materials Modelling	Course Category	Core Theory	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		Pre-requisite Courses			NIL	

Module	Syllabus	Duration(h)
Module-I	**Mathematical description of physical phenomena**-basics of partial differential equations, statistical techniques and numerical analysis. Basics of optimization schemes: Simplex method, Steepest-descent Method, Conjugate Gradient Method, Newton-Raphson Method and Genetic Algorithm based schemes.	06
Module-II	**Schemes of modelling**- empirical, phenomenological and mechanistic approach of modelling. Deterministic, stochastic and probabilistic modelling approach of materials modelling.	06
Module-III	**Quantum mechanics based materials modelling approach** – Applications of Density Functional Theory in materials modelling. Issue of convergence in Density Functional Theory calculations.	03
Module- IV	**Atomistic modelling approaches**. Classical interatomic potentials and their application for simulation of materials. Basics of Molecular Dynamics and Monte Carlo approach.	02
Module-V	**Mesoscale approach for materials modelling**- Basics of Finite Difference and Finite Element Method. Application of Finite Element Method for studying multi-physics phenomena. Cellular Automata and its application in Materials Engineering.	04
Module-VI	**Coupling of scales** for development of multiscale materials models for structure-property correlation in materials science and manufacturing. Uncertainty quantification in multiscale modelling-traditional and Bayesian approaches.	08
Module-VII	**Case-studies:** 1. Integrated Computational Materials Engineering (ICME) approach for studying plasticity in materials. 2. Multiscale modelling of design of high temperature material for turbine applications.	05
Module-VIII	**Machine Learning in Materials Science**: Introduction to Machine Learning, Data Pre-processing, Supervised Learning Algorithms including Artificial Neural Networks, Linear Regression, and Bayesian classification and Hidden Markov Models, Unsupervised Learning Algorithms, Optimization techniques, Evolutionary algorithms.	06
	Total contact hours	**40**

Learning Resources	Multiscale materials modelling: Fundamentals and applications, Z. Xiao Guo, CRC press. Multiscale Modelling: A Bayesian Perspective, Springer. Integrated Computational Materials Engineering (ICME) for Metals: Using multiscale modelling to invigorate engineering design with science, M.E. Horstemeyer, Wiley. Molecular Modelling: Principles and Applications, Andrew R. Leach, Pearson Machine Learning, Anuradha Srinivasaraghavan, Vincy Joseph, Wiley. Deep Learning using Python, S. Lovelyn Rose, L. Ashok Kumar, D. Karthika Renuka, Wiley

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">MM5221</td><td rowspan="2">Course Name</td><td rowspan="2">Design and Selection of Materials</td><td rowspan="2">Course Category</td><td rowspan="2">Departmental Elective</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>3</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Course Offering Department</td><td colspan="2">Metallurgy and Materials Engineering</td><td colspan="3">Pre-requisite Courses</td><td colspan="2">NIL</td></tr>
</table>

Module	**Syllabus**	**Duration(h)**
Module-I	Relationship between processing-structure-properties of various engineering materials	04
Module-II	Materials selection criteria-shape, micro structural factors, performance criteria in service and other strategic requirements of engineering components to be designed. Economic considerations	10
Module-III	Technologically important material properties: physical, mechanical, chemical, thermal, optical and electrical properties	06
Module-IV	Materials used in important engineering sectors	04
Module-V	Types of design, materials data and design tools	05
Module-VI	Methodology for selection of materials for the components, selection of processes to meet the design requirements	05
Module-VII	Systematic selection process-pertinent case studies, Multiple constraints; its handling strategies	04
	Total contact hours	**38**

Learning Resources	**Engineering Design: A materials and processing approach: George E Dieter. McGraw-Hill Pub.** **Materials & Design**: Michael Ashby and Kara Johnson. Elsevier Pub. **Materials and Process Selection for Engineering Design:** Mahmoud M. Farag. CRC Press Pub. **Materials Selection and Design**, Md AbdulMaleque and MohdSapuanSalit, Springer. **Selection and Use of Engineering Materials**: F A A Crane, J A CharlesJ. Furness. Butterworth-Heinemann Pub.

Course Code	MM5222	Course Name	Energy Materials	Course Category	Departmental Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		Pre-requisite Courses		NIL		

Module	Syllabus	Duration(h)
Module-I	**Properties of Materials** Electronic and Electric Properties: free electron theory, fermi energy density of states, elements of band theory, dielectric, piezoelectric, pyroelectric and ferroelectric effect. Magnetic properties: origin of magnetism, para-, dia-, ferro and ferri-magnetisms. Thermal Properties: specific heat, thermal conductivity and thermal expansion, thermoelectricity. Optical and optoelectronic properties. Superconductivity.	10
Module-II	**Basics of fuel cells and electrochemical devices** Mechanism and materials for different types of batteries, supercapacitor and hybrid fuel cells (Polymer membranes for fuel cells, PEM fuel cell, Acid/alkaline fuel cells.), electrochemical and photoelectrochemical water splitting.	4
Module-III	**Basics of batteries** Details of Pb-acid Nickel-metal hydride (Ni-MH), NiCd-alkaline battery, Ni-iron, Li/Na-ion, Mg-ion, Li/Na-S batteries, Metal-air battery, battery maintenance and safety precautions. Application of phase-change materials for energy conservation.	6
Module-III	**Basics of solar cells**; thin-film solar cells, Nano-, micro- and poly-crystalline Si for solar cells, mono-micro silicon composite structure, crystalline silicon deposition techniques, material and solar cell characterization,	6
Module-IV	**Advanced solar cell concepts and technologies** Amorphous silicon thin-film technologies, multi-junction (tandem) solar cells, stacked solar cells. Conjugated polymers, organic/plastic/flexible solar cells, polymer composites for solar cells, device fabrication and characterization	4
Module- V	**Energy harvesting materials and their applications**: Thermoelectric materials, Triboelectric materials, Piezoelectric materials, and Magnetoelectric materials	8
Module-VI	**Advanced Energy materials:** Materials used in Nuclear Power PlNTA; Materials used for storage of Hydrogen(MOF & COF)	2
	Total contact hours	**40**

Learning Resources	**Energy Materials**, Ed. Duncan W. Bruce, Dermet O'Hare, Richard I. Walton, Wiley, 2011. **Energy Storage and Conversion Materials**, Ed. Stephan Skinner, RSC Publications, 2020. **Solar Cells and Energy Materials**, Takeo Oku, De Gruyter, 2017.

Course Code	MM5223	Course Name	Surface Treatment and Modification	Course Category	Departmental Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		Pre-requisite Courses			NIL	

Module	Syllabus	Duration(h)
Module-I	**Introduction** Conventional Materials Engg., Types of Surface Modifications, Physical Modifications, Chemical Modifications, Applications of Materials Engg. towards Nanomaterials, Structure, Defects in solids, Bonds and Bands in Materials, Thermodynamics of Materials, Kinetics, Nucleation	04
Module-II	**Vacuum Science and Technology** Kinetic Theory of Gases, Gas Transport and Pumping, Vacuum Technology	06
Module -1II	**Thin-film Evaporation Processes** Physics and Chemistry of Evaporation, Film Thickness Uniformity, Evaporation Processes and Applications	06
Module-IV	**Discharges, Plasma, and Ion-Surface Interactions** Plasma Discharges and Arcs, Fundamentals of Plasma Physics, Reactions in Plasmas, Physics of Sputtering, Ion bombardment modification of growing films	04
Module-V	**Chemical Vapor Deposition** Reaction types, Thermodynamics of CVD, Gas transport, Film growth kinetics, Thermal CVD, Plasma-enhanced CVD	04
Module-VI	**Metal and metal-hybrid-composite Coating** Criteria for material selection, Electroplating, Galvanizing, Aluminizing, Metal Cladding. Merits, Industrial coating application technologies, Demerits, Types and Applications of each.	08
Module-VII	**Polymer, hybrid, and paint coating** Requirement for organic coating, Concept of thin organic coating, organic/inorganic hybrid coating, concept of paint technology, Industrial coating application technologies, Merits, Demerits, Types and Applications of each	05
Module-VIII	**Characterization of coatings and surfaces** Adhesion, Wear, Corrosion, Oxidation, Porosity, Roughness, surface defects, Residual Stress, Stability. Surface Microscopy, Scanning Probe Microscope to determine topology, X-ray photoelectron and Auger Spectroscopy, Atomic Force microscopy, Kelvin probe, Raman, Use of TEM in thin film analysis and other Spectroscopic Analysis	10
	Total contact hours	**38**

Learning Resources	**Materials Science of Thin Films**, Milton Ohring, CRC Press **Polymer Coatings: A Guide to Chemistry, Characterization, and Selected Application,** Gijsbertus de With, Wiley

Course Code	MM5224	Course Name	Joining Technology	Course Category	Departmental/ Specialization Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		Pre-requisite Courses		NIL		

Module	Syllabus	Duration(h)
Module-I	Introduction to advanced joining techniques of similar and dissimilar materials	2
Module-II	Explosive Welding and Adhesive Bonding: theory and Key Variables, Parameters, Weld Quality, Equipment and Tooling, Advantages, Limitations and Applications,	4
Module-III	Electron Beam Welding- Background of the Process, Guns, Weld Environment, Welding in Different Degrees of Vacuum, Equipment and Applications, Laser Beam Welding, Physics of Lasers, Types of Lasers, Process Parameters, Applications and Limitations.	6
Module-IV	Plasma arc welding: Plasma Arc Welding- theory and Principles, Transferred arc and Non-Transferred arc Techniques, Equipment, Joint Design Advantages, Disadvantages, and Applications, Magnetically impelled arc butt (MIAB) welding, Under Water Welding- Wet and Dry Under Water Welding	6
Module-V	Vacuum brazing- Theory, Mechanisms and Key Variables, Equipment, Stop-Off and Parting Agents, Advantages, Limitations and Applications.	6
Module-VI	Ultrasonic welding-Principles of operation, Process Characteristics and Applications,	2
Module-VII	Diffusion Welding- theory and Principle of Process, Key Variables, Intermediate Materials, Deformation Welding, Equipment, Advantages, Limitations, Materials, Applications, Cold Pressure Welding- Process, Equipment and Setup, Applications	6
Module-VIII	Friction Welding- Basic Principles, Process Variants, Different Stages of Friction Welding, Mechanism of Bonding, Influence of Process Parameters, Weld Quality and Process Control, Joining of Dissimilar Materials, Advantages, Limitations and Applications, Friction Stir Welding-Metal flow phenomena, tools, process variables and applications, Friction Stir Processing- Process, Application	8
	Total contact hours	**40**

Learning Resources	**Welding Engineers Hand Book-** ASHE Vol . I, II, III and IV. Parmar R.S., **Welding Processes and Technology**, Khanna Publishers, Delhi Rossi, **Welding Engineering**, McGraw Hill. Schwartz M.M., **Metals Joining Manual**, McGraw-Hill Inc. Udin et al., **Welding for Engineers**, John Wiley & Sons.

Course Code	MM5225	*Course Name*	Engineering Tribology	*Course Category*	Departmental Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*			*NIL*	

Module	Syllabus	Duration(h)
Module-I	**Introduction to Tribology:** Structure of surfaces, Surface topography, Chemical and physical state of the solid surface; Materials Engg. for tribology	04
Module-II	**Fundamental of contact between solid surfaces**	04
Module-III	**Friction and its measurement**	04
Module- IV	**Wear and its measurement:** Classification of wear; Adhesive, Abrasive, Erosive, Cavitation, Corrosive, Oxidative, Fatigue and Fretting Wear	06
Module-V	**Wear of** alloys, polymers and ceramic; Mechanisms of wear; Wear Maps	04
Module-VI	**Lubricant:** Classification of lubricants, Physical properties of lubricants, Lubricants and their composition, Viscosity and its measurements	04
Module-VII	**Hydrodynamic Lubrication:** Frictional force, power loss, mechanism of pressure development, Reynold's equation, Navier-Stokes equation, Coefficient of friction	04
Module-VIII	**Hydrostatic Lubrication:** Hydrostatic step bearings, load carrying capacity, Oil flow through the hydrostatic step bearing	04
Module-IX	**Tribology in practice:** Material selection, Improved design and Materials Engg.;	02
Module-X	**Design of** (*any one*)- Cutting tool, Low friction surface, Seal	02
Module-XI	**Bio-tribology and Nano-tribology**	02
	Total contact hours	**40**

Learning Resources	**Engineering Tribology:** G. Stachowiak and A. Batchelor, Butterworth-Heinemann **Introduction to Tribology:** B. Bhushan, John Wiley & Sons **Fundamentals of Tribology:** R. Gohar and H. Rahnejat, World Scientific **Friction, Wear, Lubrication:** K.C. Ludema and L. Ajayi, CRC Press

Course Code	MM5226	*Course Name*	Microsystem Technology	*Course Category*	Departmental Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*		NIL		

Module	**Syllabus**	**Duration(h)**
Module-I	**Introduction to micro-electro mechanical systems (MEMS)** Examples of Common devices (such as Inertial Measurement Units)	2
Module-II	**Materials for MEMS** Common materials used and their properties(metals, polymers, ceramics and composites utilized in sensors and actuators); Piezoelectric materials and composites	8
Module-III	**Micromachining techniques** Thin-film deposition (physical and chemical vapour deposition techniques); lithography (ultraviolet lithography, electron-beam lithography, soft-lithography); etching; bonding.	10
Module- IV	**Process integration** Case Studies; Integration of nanomaterials to MEMS.	4
Module-V	**Packaging of MEMS devices** Packaging materials and processes; Case Studies	10
Module-VI	**Reliability of MEMS devices** Failure related to materials; Case Studies	4
	Total contact hours	**38**

Learning Resources	S. D. Senturia, "**Microsystem Design**" Springer. N. Maluf, "**An Introduction to Microelectromechanical Systems Engineering**", Artech House A. L. Hartzell, M. G. da Silva, and Herbert R. Shea, "**MEMS Reliability**", Springer M.J. Madou, "**Fundamentals of micro fabrication: The Science of Miniaturization**, Second Edition", CRC Press, USA, 2002. Reza Ghodssiand Pinyen Lin (Editors), "**MEMS Materials and Processes Handbook**", Springer, 2011.

Course Code	MM5261	*Course Name*	Nanostructures and Nanomaterials	*Course Category*	Open Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*			*NIL*	

Module	**Syllabus**	**Duration(h)**
Module-I	Introduction to nanostructures and nanomaterials.	01
Module-II	Classification of nanomaterials. Effect of size on the properties of materials and nanomaterials. Microstructural features of nanomaterials. Characterization of nanostructures and nanomaterials.	08
Module - III	Synthesis of Nanomaterials via chemical routes: Chemical precipitation and coprecipitation;Metal nanocrystals by reduction, Sol-gel synthesis; Solvothermal synthesis; Thermolysis, Microwave heating synthesis; Sonochemical synthesis; Electrochemical synthesis; , Photochemical synthesis, Synthesis in supercritical fluids	08
Module -1V	Preparation of Nanomaterials by Physical Methods: Inert gas condensation, Arc discharge, Plasma arc technique, Laser ablation, Ball Milling, Chemical vapour deposition, Electro deposition	06
Module-V	Properties of nanowires, quantum wells and quantum dots	06
Module VI	Carbon nanostructures : Synthesis and properties of fullerenes, carbon nanotubes, Graphene	08
Module-VII	Application of Nanostructures and nanomaterials	01
	Total contact hours	**38**

Learning Resources	**Nanostructures and nanomaterials : Synthesis, properties & applications** by Guozhong Cao **Chemistry of nanomaterials : Synthesis, properties and applications** by CNR Rao et.al.

<table>
<tr><td>Course Code</td><td>MM5262</td><td>Course Name</td><td>Biomedical Materials and Devices</td><td>Course Category</td><td>Open Elective</td><td>L
3</td><td>T
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<tr><td colspan="2">Course Offering Department</td><td colspan="2">Metallurgy and Materials Engineering</td><td colspan="3">Pre-requisite Courses</td><td colspan="2">NIL</td></tr>
</table>

Module	Syllabus	Duration(h)
Module-I	**Basics:** Materials and Biology: Metal, Ceramic, Polymer, Composite; Bioresorbale and biodegradable materials	04
Module-II	**Biomaterials Surfaces:** Physics; Surface Structure and Properties; Surface Energy; Adsorption, Segregation, and Reconstruction at Surfaces; Reactions at surfaces; Protein-Surface Interactions; Host Response to Biomaterials; Cell Adhesion Mechanisms; Coagulation Cascade	08
Module -1II	**Testing of biomaterials:** In vitro and in vivo assessment; evaluation of blood material interactions; Microscopic techniques; Spectroscopic Techniques	06
Module-IV	**Degradation of Materials**: Degradation of polymers; Degradation effect on metals and ceramics	04
Module-V	**Materials in medicine, biology and artificial organs:** Cardiovascular Medical Devices; Implantable Cardiac Assist Devices; Orthopedic Applications; Dental Implantation; Intraocular Lens Implants; Drug Delivery Systems; Biomedical Sensors and Biosensors	12
Module-VI	**Case studies:** Fiber Optic Biosensors, Nanobarcodes; Drug Delivery: Controlled Release; Mechanical Pumps; Artificial Pancreas, Cartilage, Nerve Regeneration	04
	Total contact hours	**38**

Learning Resources	Ratner, Buddy D., et al. ***Biomaterials Science: An Introduction to Materials in Medicine*** B.Basu, D.Katti and Ashok Kumar;Advanced Biomaterials: Fundamentals,Processing and Applications; John Wiley & Sons, Inc., USA (ISBN: 978-0-470-19340-2), September, 2009.

Course Code	MM5263	*Course Name*	Non-Destructive Testing	*Course Category*	Open Elective	L	T	P
						3	0	0
Course Offering Department		Metallurgy and Materials Engineering		*Pre-requisite Courses*			NIL	

Module	Syllabus	Duration(h)
Module-I	**Fundamentals:** Introduction to destructive and non-destructive testing. Scope and limitations of NDT, Defects in casting, forging, heat-treated and other products namely rolled/machined, welded products etc., Causes of defects.	04
Module-II	**Visual examination**: Methods. Different visual examination aids.	02
Module-III	**Leak and pressure testing of industrial components**: Various methods of pressure and leak testing underlying principles of these testing systems.	03
Module-IV	**Dye penetrant method**: Liquid penetrant testing – procedure; penetrant testing materials, penetrant testing method – sensitivity; application and limitations.	04
Module-V	**Magnetic particle testing**: Definition and principle; magnetizing technique, procedure, equipment, sensitivity and limitations.	04
Module- VI	**Ultrasonic methods**: Basic principles of wave propagation, types of waves, methods of UT, their advantages and limitations. Various types of transducers. Calibration methods, use of standard blocks. inspection methods, technique for normal beam inspection, flaw characterization technique, ultrasonic flaw detection equipment, modes of display, Characterization of defects in castings, forgings, rolled and welded products by UT. Thickness determination by ultrasonic method. Study of A, B and C scan presentations. immersion testing, advantage, limitations; acoustic emission testing – principles of AET and techniques.	06
Module-VII	**Radiographic testing of components**: X-ray and Gamma-Ray radiography. Their principles, methods of generation. Industrial radiography techniques, applications, limitations. Types of films, screens and penetrameters. Interpretation of radiographs. Real time X-ray radiography. Safety in industrial radiography.	04
Module-VIII	**Electrical and thermal methods of NDT**: Conductivity & resistivity methods and their applications. Eddy current testing. Principle, instrument, techniques, sensitivity, application, limitation,Thermal method: principle, equipment, advantages and limitations.	04
Module-IX	**Advanced methods of NDT**: Holography, Tomography, MRI etc.	03
Module-X	**Selection of NDT Methods**: VI, LPT, MPT, ECT, RT, UT, AET and thermography; reliability in NDT.	04
	Total contact hours	**38**

Learning Resources	A. V. K. Suryanarayana: **Testing of Metallic Materials**. PHI Pub. Baldev Raj, T. Jayakumar, M. Thavasimuthu: **Practical Non-Destructive Testing**. Narosa Pub. House. Ravi Prakash: **Non-Destructive Testing Techniques**. New Age International Pub. ASM Metals Handbook (Vol. 17): **Non-Destructive Evaluation of Materials.** American Society of Metals, Metals Park, Ohio, USA. Paul E. Mix**: Introduction to Non-destructive Testing**: A Training Guide. Wiley Pub.