B. Tech. (Four Years)

Course Curriculum and Syllabi

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

First (1st) Semester								
Sl. No.	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load per week**	**Marks**
			L	**T**	**P**			
1	**Mathematics – I**	**MA1101**	3	1	0	4	4	100
2	**Chemistry/Physics**	**CH1101/ PH1101**	3/4	0	0	3/4	3/4	100
3	**Intro to Computing/Basic Electrical Engineering**	**CS1101/ EE1101**	3/4	0	0	3/4	3/4	100
4	**Mechanics/Environment and Ecology**	**AM1101/ CE1101**	4/3	0	0	4/3	4/3	100
5	**Professional Communication in English / Sociology and Professional Ethics**	**HU1101/ HU1102**	3/3	0	0	3/3	3/3	100
	Theory Sub-Total		**16/17**	**1**	**0**	**17/18**	**17/18**	**500**
6	**Chemistry Lab/Physics Lab**	**CH1171/ PH1171**	0	0	3	2	3	50
7	**Computer Lab/ Electrical Lab**	**CS1171/ EE1171**	0	0	3	2	3	50
8	**Drawing/Workshop**	**AM1171/ WS1171**	0	1/0	3/3	3/2	4/3	50
9	**NSS/NCC/PT/Yoga**	**SA1171**				*R**		
	Sessional Sub-Total		**0**	**1/0**	**9**	**7/6**	**10/9**	**200**
						1st Semester Total	**24**	**27**	**700**

R: Required (Non-credit but with grade)

Second (2nd) Semester								
Sl. No.	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load per week**	**Marks**
			L	**T**	**P**			
1	**Mathematics – II**	**MA1201**	3	1	0	4	4	100
2	**Physics/Chemistry**	**PH1201/ CH1201**	4/3	0	0	4/3	4/3	100
3	**Basic Electrical Engineering/ Intro to Computing**	**EE1201/ CS1201**	4/3	0	0	4/3	4/3	100
4	**Environment & Ecology/ Mechanics**	**CE 1201/ AM1201**	3/4	0	0	3/4	3/4	100
5	**Sociology & Professional Ethics / Professional Communication in English**	**HU1102/ HU1101**	3/3	0	0	3/3	3/3	100
	Theory Sub-Total		**15**	**1**	**0**	**16**	**16**	**500**
6	**Physics Lab/Chemistry Lab**	**PH1271/ CH1271**	0	0	3	2	3	50
7	**Electrical Lab/Computer Lab**	**EE1271/CS1271**	0	0	3	2	3	50
8	**Workshop/Drawing**	**WS1271/ AM1271**	0	0/1	3/3	2/3	3/4	50
9	**NSS/NCC/PT/Yoga**	**SA1271**				R*		
	Sessional Sub-Total		**0**	**0/1**	**9**	**6/7**	**9/10**	**200**
	2nd Semester Total					**24**	**27**	**700**

Third (3rd) Semester								
Sl. No.	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load per week**	**Marks**
			L	**T**	**P**			
1	**Mathematics-III**	**MA21xx**	3	0	0	3	3	100
2	***(Core Theory – I)* Metallurgical Thermodynamics**	**MM2101**	3	1	0	4	4	100
3	***(Core Theory – II)* Transport Phenomena and Rate Processes**	**MM2102**	3	0	0	3	3	100
4	***(Core Theory – III)* Physical Metallurgy of Ferrous Alloys**	**MM2103**	3	0	0	3	3	100
5	***(Core Theory – IV)* Physics of Materials**	**MM2104**	3	0	0	3	3	100
	Theory Sub-Total		**15**	**1**	**0**	**16**	**16**	**500**
6	***(Core Lab – I)* Transport Phenomena and Rate Processes Lab.**	**MM2171**	0	0	3	2	3	50
7	***(Core Lab –II)* Physical Metallurgy Lab.**	**MM2172**	0	0	3	2	3	50
8	***(Core Lab –III)* Physics of Materials lab.**	**MM2173**	0	0	3	2	3	50
9	**Mini Project**	**MM2191**	0	0	0	2	0	50
	Sessional Sub-Total		**0**	**0**	**9**	**8**	**9**	**200**
	3rd Semester Total					**24**	**25**	**700**

Fourth (4th) Semester								
Sl. No.	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load per week**	**Marks**
			L	**T**	**P**			
1	***(Core Theory – V)*** **Principles of Extractive Metallurgy**	**MM2205**	3	0	0	3	3	100
2	***(Core Theory – VI)*** **Heat Treatment**	**MM2206**	3	1	0	4	4	100
3	***(Core Theory – VII)*** **Deformation Behaviour of Materials**	**MM2207**	3	0	0	3	3	100
4	***(Core Theory – VIII)*** **Computational Materials Engineering**	**MM2208**	3	0	0	3	3	100
5	***(Core Theory – IX)*** **Iron Making**	**MM2209**	3	0	0	3	3	100
	Theory Sub-Total		**15**	**1**	**0**	**16**	**16**	**500**
6	***(Core Lab – IV)*** **Extractive Metallurgy Lab.**	**MM2274**	0	0	3	2	3	50
7	***(Core Lab – V)*** **Heat Treatment Lab.**	**MM2275**	0	0	3	2	3	50
8	***(Core Lab – VI)*** **Deformation Behaviour of Materials Lab.**	**MM2276**	0	0	3	2	3	50
9	***(Core Lab-VII)*** **Computational Materials Engineering Lab.**	**MM2277**	0	0	3	2	0	50
	Sessional Sub-Total		**0**	**0**	**12**	**8**	**9**	**200**
	4th Semester Total					**24**	**25**	**700**

Fifth (5th) Semester								
Sl. No.	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load per week**	**Marks**
			L	**T**	**P**			
1	***(Core Theory – X)* Steel Making**	**MM3110**	3	1	0	4	4	100
2	***(Core Theory – XI)* Metal Casting Technology**	**MM3111**	3	1	0	4	4	100
3	***(Core Theory - XII)* Joining of Materials**	**MM3112**	3	0	0	3	3	100
4	***(Core Theory – XIII)* X-Ray and Electron Diffraction**	**MM3113**	3	0	0	3	3	100
5	***(Core Elective-I)***		3	0	0	3	3	100
	(i) Manufacturing Technology	**MM3122**						
	(ii) Electronic and Magnetic materials	**MM3123**						
	(iii) Energy Materials	**MM3124**						
	Theory Sub-Total		**15**	**2**	**0**	**17**	**17**	**500**
6	***(Core Lab – VIII)* Metal Casting Technology Lab.**	**MM3178**	0	0	3	2	3	50
7	***(Core Lab – IX)* Joining of Materials Lab.**	**MM3179**	0	0	3	2	3	50
8	***(Core Lab – X)* X-Ray Diffraction and Electron Microscopy Lab.**	**MM3180**	0	0	3	2	3	50
	Sessional Sub-Total		**0**	**0**	**9**	**6**	**9**	**150**
	5th Semester Total					**23**	**26**	**650**

Sixth (6th) Semester								
Sl. No.	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load per week**	**Marks**
			L	**T**	**P**			
1	***(Core Theory – XIV)* Mechanical Testing of Materials**	**MM3214**	3	1	0	4	4	100
2	***(Core Theory – XV)* Alloy Steel and Cast Iron**	**MM3215**	3	1	0	4	4	100
3	***(Core Theory – XVI)* Physical Metallurgy of Non-Ferrous Alloys**	**MM3216**	3	0	0	3	3	100
4	***(Core Theory – XVII)* Materials Characterization**	**MM3217**	3	0	0	3	3	100
5	***(Core Theory – XVIII)* Metal Forming Technology**	**MM3218**	3	0	0	3	3	100
	Theory Sub-Total		**15**	**2**	**0**	**17**	**17**	**500**
6	***(Core Lab- XI)* Mechanical Testing Laboratory**	**MM3281**	0	0	3	2	3	50
7	***(Core Lab – XII)* Materials Characterization Lab.**	**MM3282**	0	0	3	2	3	50
8	***(Core Lab – XIII)* Material Processing Lab.**	**MM3283**	0	0	3	2	3	50
	Sessional Sub-Total		**0**	**0**	**9**	**6**	**9**	**150**
	6th Semester Total					**23**	**26**	**650**

Seventh (7th) Semester								
Sl. No.	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load per week**	**Marks**
			L	**T**	**P**			
1	***(Core Theory - XIX)* Ceramic and Composite Materials**	**MM4119**	3	0	0	3	3	100
2	***(Core Theory - XX)* Degradation of Materials**	**MM4120**	3	0	0	3	3	100
3	***(Core Elective – II)***		3	0	0	3	3	100
	(i) Powder Metallurgy	**MM4125**						
	(ii) Stainless Steels	**MM4126**						
	(iii) Polymeric Materials	**MM4127**						
4	**Finance Economics and Management for Engineers**	**HU4101**	3	0	0	3	3	100
	Theory Sub-Total		**12**	**0**	**0**	**12**	**12**	**400**
5	**(Core Lab – XIV) Ceramic and Composite Materials Lab.**	**MM4184**	0	0	3	2	3	50
6	**(Core Lab – XV) Degradation of Materials Lab.**	**MM4185**	0	0	3	2	3	50
7	**B.Tech. Project/ 1**	**MM4192**	0	0	2	4	2	100
8	**Internship from 4th/6th Sem (Evaluation)**	**MM4193**	0	0	0	2	0	50
	Sessional Sub-Total		**0**	**0**	**8**	**10**	**8**	**250**
	7th Semester Total					**22**	**20**	**650**

Eighth (8th) Semester								
Sl. No.	**Course Name**	**Course Code**	**Class Load/Week**			**Credit**	**Class load per week**	**Marks**
			L	**T**	**P**			
1	***(Core Theory – XXI)* Design and Selection of Materials**	**MM4221**	3	1	0	3	4	100
2	***(Core Elective –III)***		3	0	0	3	3	100
	(i) **Fracture and Failure Analysis**	**MM4228**						
	(ii) **Thin Films and Coatings**	**MM4229**						
	(iii) Non-destructive Characterization	**MM4230**						
3	***(Open Elective-I)***		3	0	0	3	3	100
	(i) **Nanomaterials**	**MM4261**						
	(iii) **Biomaterials**	**MM4262**						
	(iv) **Engineering Composite Materials**	**MM4263**						
	Theory Sub-Total		**9**	**1**	**0**	**10**	**10**	**300**
4	**B. Tech. Project /2**	**MM4294**	0	0	2	8	2	200
5	**Seminar II**	**MM4295**	0	0	0	2	0	50
6	**Comprehensive Viva-voce**	**MM4296**	0	0	0	2	0	100
	Sessional Sub-Total		**0**	**0**	**2**	**12**	**2**	**350**
8th Semester Total						**22**	**12**	**650**

SYLLABUS

(Individual Course Contents)

Course Code	**MM2101**	**Course Name**	**Metallurgical Thermodynamics**	**Course Category**	Core Theory	L	T	P
						3	1	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**	*NIL*	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	**Fundamental concepts in thermodynamics**: System, Surroundings, State, Extensive and Intensive properties and Heterogeneous systems, Internal energy, Heat capacity, Enthalpy, Isothermal and Isobaric processes	4
Module-II	**Laws of thermodynamics:** Entropy, Fugacity, Activity, Zeroeth, First, Second, Third laws and their applications	5
Module-III	**Free Energy** – Gibbs and Helmholtz Free Energy, Maxwell's Equations, Ellingham Diagram, Transformation Formula	5
Module- IV	**Equilibrium:** Concept of Equilibrium, Quasistatic Processes and Equilibrium constants, Equilibrium diagrams, Phase stability diagrams, stability of phases: intermetalic compounds and intermediate phases	5
Module-V	**Solutions:** Solutions and Partial molar quantities, Laws for ideal and non-ideal solutions, Concepts of standard states, thermodynamics of slags, basic concepts of ordered solution and some common types of ordering in alloys.	6
Module-VI	**Phase formation and stability**: Thermodynamics and theories of alloying, Phase rule applications, free-energy-composition diagrams and determination of liquidus, solidus and solvus lines, Spinodal Decomposition, Chemical Potential	7
Module-VII	**Thermal Analysis of Materials:** Differential Scanning Calorimetry, Thermogravimetric Analysis and Dilatometry	5

Learning Resources	Introduction to metallurgical thermodynamics by David R. Gaskell: Taylor & Francis Introduction to Materials and Metallurgical Thermodynamics by A. Ghosh published by PHI

Course Code	MM2102	Course Name	Transport Phenomena and Rate Processes	Course Category	Core Theory	L	T	P
						3	0	0

Pre-requisite Courses		Co-requisite Courses		*NIL*	Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*	

Module	Syllabus	Duration (h)
Module-I	**Introduction**: Homogeneous and heterogeneous reactions, Introductory concepts of kinetics of heterogeneous reactions, Concepts of rate controlling step and virtual maximum rate; Identification of reaction mechanisms	4
Module-II	**Kinetics of Homogeneous Chemical Reactions**: Law of mass action, Integrated Rate Equations, Variation of rate constant with temperature, Arrhenius equation, Theory of Absolute Reaction Rates	4
Module-III	**Gas-Solid and Gas-Liquid Interfacial Reactions**: Adsorption, Adsorption Isotherms, Examples of slow surface reactions in high temperature metallurgy	6
Module- IV	**Momentum Transport**: Newton's law of viscosity, Shell momentum balance, Concepts of Laminar and Turbulent flow, Friction factor	8
Module-V	**Energy Transport**: Fourier's law of heat conduction, Theories of thermal conductivity, Shell Energy Balances and Temepearture Distribution in Solids	8
Module-VI	**Mass Transport**: Steady and unsteady diffusion, Fick's laws of diffusion, Applications of diffusion equations in metallurgy, Diffusion: Fick's laws-their solution and application: Atomic mechanism of different kinds of diffusion, kirkendall effects, uphill diffusion.	6
Module-VII	**Kinetics of Reactions of Porous Solids with Gases:** Diffusion of gases through porous solids, Kinetics of reduction of oxides by gases, Kinetics of gasification of carbon by carbon dioxide, Kinetics of reduction of iron oxide by carbon	6

Learning Resources	D. R. Poirier, G. H. Geiger, Wiley, "Transport Phenomena in Materials Processing". A. Ghosh, S. Ghosh, S. (2014), Phi Learning Pvt. Ltd. "A textbook of metallurgical kinetics" R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot. Wiley International edition, "Transport Phenomena". Julian Szekely, Academic Press, University of Michigan, "Fluid flow phenomena in metals processing" P.G. Shewmon, 2nd Edition, 1991, John Wiley and Sons, "Diffusion in solids"

Course Code	**MM2103**	**Course Name**	**Physical Metallurgy of Ferrous Alloys**	**Course Category**	Core Theory	L	T	P
						3	0	0

Pre-requisite Courses		**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Introduction and classification of phase transformations	2
Module-II	**Principles of heat treatment of steels** Fe-Fe3C diagram; Formation of austenite - kinetics and mechanism; Grain growth and size of austenite grain; Homogeneity of austenite, Selection of austenitizing temperature and time.	4
Module-III	**Phase transformation in steels** Thermodynamics, Kinetics and Mechanisms of ferritic, pearlitic, Bainitic and Martensitic Transformations.	8
Module-IV	Crystal structure and atomic arrangement in solids: Defects in crystals: dimension, origin and their effects on properties; concepts of grains, grain boundaries and texture. (in more detail: Poiint group, Space group, Symmetry Elements)	6
Module- V	Construction, interpretation of different types of equilibrium phase diagrams. Interpretation of ternary equilibrium phase diagrams. Description of some important equilibrium phase diagrams e.g. metal-nonmetal, metal-metal, ceramic-ceramic etc.	8
Module-VI	Solidification of metals and alloys; thermal and constitutional super-cooling, cooling curves, coring and micro/macro segregations.	6
Module-VI	Optical microscopy: principles of different techniques, specimen preparation, Principles of various temperature measurement techniques. Thermal analysis measurement techniques.	4
Module-VII	Significance of structure-properties-processing relationship of engineering materials	4

Learning Resources	1. Physical Metallurgy, Robert W. Cahn and Peter Haasen 2. Physical Metallurgy and Advanced Materials, R. E. Smallman and A.H.W. Ngan 3. Modern Physical Metallurgy and Materials Engineering, R. E. Smallman and R. J. Bishop 4. Physical Metallurgy Principles, Robert E. Reed-Hill 5. Physical Metallurgy, Vijendra Singh

Course Code	MM2104	Course Name	Physics of Materials	Course Category	Core Theory	L	T	P
						3	0	0

Pre-requisite Courses		Co-requisite Courses		*NIL*	Progressive Courses	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		Data Book / Codes/Standards	*NIL*	

Module	Syllabus	Duration (h)
Module-I	**Electron theory of metals**: de Broglie waves, uncertainty principle, Drude's Theory, wave function and Schrodinger equation; Free electron theory, concepts of density of states, probability interpretation, particle on a chain, potential barrier and quantum tunneling, potential well, qualitative summary of simple harmonic oscillation and Hydrogen atom. Occupation probability and examples.	7
Module-II	**Zone theory**: Brillouin zone, free electron band diagrams, potential in a crystal, electron dynamics and concept of holes, conductivity in relation to band structure, band structure of metals, semiconductors and insulators; direct and indirect band-gap semiconductors, intrinsic and extrinsic semiconductors. Ionic conduction - review of defect equilibrium and diffusion mechanisms, theory of ionic conduction, conduction in glasses, effect of stoichiometric and extrinsic defects on conduction, applications in sensors and batteries.	7
Module-III	**Dielectric materials**: Dielectric constant and polarization, linear dielectric materials, capacitors and insulators, polarization mechanism, non-linear dielectrics – pyro-, piezo and ferro-electric thermo-electric properties, hysteresis and ferro-electric domains and applications.	7
Module- IV	**Optical materials**: electron-hole recombination, solid-state LED's, Lasers and IR detectors, band gap engineering; Light interaction with materials – transparency, translucency and opacity, refraction and refractive index; reflection, absorption and transmission.	7
Module-V	Magnetic field, flux density, susceptibility and permeability; Orbital and spin, permanent magnetic moment of atoms, diamagnetism, paramagnetism and pauli paramagnetism, ferro-, anti-ferro and ferri- magnetism, Fe, Co, Ni and alloy additions, ferrites, magnetic hysteresis, soft and hard magnetic materials.	7
Module-VI	Superconductivity	2

Learning Resources	Physics of Materials: Essential Concepts of Solid-State Physics, Prathap Haridoss, Wiley (2015) Physics of Materials, 1st Edition, Y. Quere CRC Press (1998) Solid State Physics, 2nd edition, J.S. Blakemore, Cambridge University Press (1985)

Course Code	**MM2171**	**Course Name**	**Transport Phenomena and Rate Processes Lab.**	**Course Category**	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses	*NIL*	**Co-requisite Courses**	*NIL*	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Estimation of activation energy	6
Module-II	Diffusion kinetics	6
Module-III	Oxidation of metals: Study of kinetics of oxidation of various metal samples at different temperatures	6
Module- IV	Kinetics of mixing	6
Module-V	Kinetics of direct reduction	6
Module-VI	Cementation kinetics	6

Learning Resources	• Metallurgical Thermodynamics Kinetics by S. K. Dutta and A. B. Lele, S Chand and Company Limited, New Delhi • A Text Book of Metallurgical Kinetics by A. Ghosh and S. Ghosh, PHI Learning Private Limited • A first Course on Iron and Steelmaking, by D. Mazumdar, Universities Press – IIM • Kinetics of Metallurgical Reactions by H. S. Ray, Oxford & IBH publishing Co. Pvt. Ltd • Heat and Mass Transfer by R. K. Rajput, S Chand and Company Limited, New Delhi

Course Code	MM2172	Course Name	Physical Metallurgy Laboratory	Course Category	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses		Co-requisite Courses	Physical Metallurgy	Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-I	Preparation of scratch free samples and demonstration of optical microscopes	3
Module-II	Evaluation of inclusion rating of scratch free samples	3
Module-III	Study of microstructure of Armco Iron and IF steel	3
Module-IV	Study of microstructure of 0.3 wt% C steel annealed, normalized, oil quenched, and water quenched from 900˚C	3
Module-V	Study of microstructure of 0.5 wt% C steel annealed, normalized, oil quenched, and water quenched from 850˚C	3
Module-VI	Study of microstructure of 0.8 wt% C steel annealed, normalized, oil quenched, and water quenched from 850˚C	3
Module-VII	Study of microstructure of 1.1 wt% C steel annealed, normalized, oil quenched, and water quenched from 850˚C	3
Module-VIII	Study of Microstructure of various types cast iron	3
Module-IX	Evaluation of microstructure and macrostructure of annealed Cu, Al, Mg, Zn etc.	3
Module-X	Evaluation of microstructure and macrostructure of Ti and Ti based alloys	3
Module-XI	Study of microstructure of different types of brasses (Cu-30Zn and Cu-40Zn) and bronzes (tin bronze, P bronze, Al bronze)	3
Module-XII	Recovery, recrystallization and grain growth of deformed Cu	3
Module-XIII	Identification of unknown samples	3

Course Code	**MM2173**	**Course Name**	**Physics of Materials Laboratory**	**Course Category**	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses		**Co-requisite Courses**	Physics of Materials	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Atomic Packing: Model (Software: VESTA)	3
Module-II	Crystal Structure determination using X-rays	3
Module-III	Concept of diffraction and reciprocal lattice and stereographic projection	6
Module-IV	SEM orientation: Electron-Matter interaction outcome	3
Module-V	Resistivity and conductivity measurement	6
Module-VI	Determination of bandap	3
Module-VII	Determination of electrical mobility from transistor I-V characteristic	3
Module-VIII	Measurement of dielectric properties: Determination of dielectric constant, relaxation time, analysis of Nyquist plot	6
Module-IX	Case Studies and problem solving: Identification of different physics involved in some practical problems and approach towards solving the problem related to materials engineering	9

Course Code	**MM2205**	**Course Name**	**Principles of Extractive Metallurgy**	**Course Category**	Core Theory	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**	*NIL*	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	**Introduction**: Important ores and minerals and their occurrence in India; Importance of mineral-dressing	2
Module-II	**Mineral dressing**: Various Comminution Processes - theories involved, brief description and applications, various concentration techniques and their applications, mineral dressing circuits and flowsheets	8
Module-III	**Unit Processes in Pyrometallurgy**: Introduction, Calcination, Roasting, Agglomeration, Reduction smelting, Matte smelting, Flash smelting, and Converting	12
Module- IV	**Unit Processes in Hydrometallurgy**: Introduction, Leaching, Purification of Leach Liquor, Solvent Extraction and Ion-exchange Processes, Techniques of Metal Recovery from Aqueous phase	6
Module-V	**Unit Processes in Electrometallurgy**: Introduction, Faraday's laws of electrolysis, concept of overvoltage, limiting current density, Electrowinning and Electro-refining with reference to copper, zinc and aluminium	6
Module-VI	**Flow sheets and numerical calculations**: Flow-charts, Material balance and Heat balance	2

Learning Resources	1. Principles of Extractive Metallurgy - A. Ghosh, and H. S. Ray 2. Non-ferrous Extractive Metallurgy - H. S. Ray, R. Sridhar and K. C. Abraham 3. Extractive Metallurgy Principles - T. Rosenqvist 4. Extractive Metallurgy - J. Gilchrist

	MM2206	**Course Name**	**Heat Treatment**			L	T	P

Course Code				**Course Category**	Core Theory	**3**	**1**	**0**

Pre-requisite Courses	*Nil*	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	Syllabus	Duration (h)
Module-I	**Introduction and classification of heat treatment processes** Various annealing, Normalizing, Hardening and Tempering treatments; Heat treatment-Microstructure-Property correlations.	8
Module- II	**TTT and CCT diagrams** Construction and utility of T-T-T and C-C-T diagrams, Critical cooling rate, Factors affect the T-T-T and C-C-T diagrams; Effect of Alloying elements.	6
Module-III	**Hardenability** Significance, Critical and ideal critical diameter, Jominy End Quench method, Factors affecting hardenability. Characteristics of quenchants, Different quenching media. Development of residual stresses, Quench cracking.	6
Module-IV	**Thermo-mechanical treatments** Principles and processes- austempering, martempering, patenting, ausforming etc. HSLA steels and rebars.	6
Module-V	**Heat treatment of different types of steels** Classifications, Role of major alloying elements, heat treatment process and microstructural changes; Retained austenite, Sub-zero treatment	3
Module-VI	**Surface hardening of steels** Classification, Principles, Case carburizing (solid, liquid and gas), Nitriding, Cyaniding, Carbonitriding, Plasma nitriding, Selective hardening, Flame hardening, Induction hardening, Laser hardening etc. Measurement of case depth and its relation with time and temperature.	4
Module-VII	**Design for heat treatment** Heat treatment furnaces- their temperature and atmosphere control; Defects in heat treated parts - Causes and remedies; Automation.	2

Learning Resources	Rajan, T.V., Rajan, T.S., Sharma, C.P. and Sharma, A., 2011. *Heat treatment: principles and techniques*. PHI Learning Pvt. Ltd.. Gotten, G.E. ed., 2006. *Steel heat treatment: metallurgy and technologies*. CRC press. Sharma, R.C., 2003. *Principles of heat treatment of steels*. New Age International. Bonami, G.J., 2010. *Heat treatment: theory, techniques, and applications*. Nova Science Publishers

Course Code	**MM2207**	**Course Name**	**Deformation Behaviour of Materials**	**Course Category**	Core Theory	L	T	P
						3	**1**	**0**

Pre-requisite Courses	*Nil*	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	**Introduction to deformation behaviour:** Concept of stresses and strains; engineering and true stress/strain; analysis of simple tension test data	6
Module-II	**Theory of Elasticity:** State of stress at a point, State of plane stress, Principal stresses and planes, Mohr's circle of stress (2D), State of stress in 3D; Strain at a point: Definition of normal and shear strains; Concept of hydrostatic stress and stress deviator; Elastic stress-strain relationships; Elastic strain energy	6
Module-III	**Theory of Plasticity:** Flow Curve, power-law erelationship; Relationship between true stress and engineering stress; Yield criteria for ductile metals: Von Mises' criterion and Tresca criterion; Combined stress tests; Yield locus; Octahedral shear stress and shear strain; Invariants of stress and strain; Plastic stess-strain relationships: Levy-Mises equations and Prandtl-Reuss equations	8
Module- IV	**Plastic deformation of a single crystal:** Review of crystal planes and directions; Point defects; Line defects; Deformation by slip; Critically Resolved Shear Stress; Deformation by twinning; Stacking faults; Generalized flow curve for a FCC single crystal	6
Module-V	**Dislocation theory**: Edge, screw and mixed dislocations; Burgers vector and Burgers circuit; Peierl-Nabarro stress; Cross-slip of screw dislocations; Dislocation reactions; Dislocations in FCC lattice:Partial disloactions, Lomer-Cottrell barrier; Dislocations in HCP lattice and in BCC lattice; Stress-field of dislocations; Elastic strain energy of dislocations; Force between dislocations; Dislocation climb; Intersection of Dislocations; Sources of dislocations; Multiplication of dislocations; Interaction between adislocation and a point defect	8
Module-VI	**Strengthening Mechanisms**: Grain boundaries; Equi-chesive temperature; Hall-Petch relationship; Yield Point phenomenon; Strain-aging; Solid-sloution strengthening; Strenthening from fine particles: Age hardening; Fibre strengthening; Martensite strengthening; Ausforming; Strain hardening: cold-worked structure; Effect of annealing on cold-worked metal; Bauschinger effect	8

Learning Resources	G.E. Dieter: Mechanical metallurgy, McGraw Hill Book Company, New Delhi, 1986. J.N. Harris: Mechanical Working of Metals- Theory and Practice, Pergamon Press, Oxford, 1983. J. Lin, D. Balint, M. Pietrzyk: Microstructure evolution in metal-forming processes, Woodhead Publishing Limited, 2012. W. F. Hosford and R. M.Caddell: Metal Forming: Mechanics and Metallurgy, Prentice-Hall, 2011. A.S.M. Handbook Vol. 14, Forming and Forging, ASM International

Course Code	**MM2208**	**Course Name**	**Principles of Extractive Metallurgy**	**Course Category**	Core Theory	L	T	P
						3	**1**	**0**

Pre-requisite Courses	*Nil*	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Need of Computational Materials Engineering: Examples of challenges in design of materials for challenging applications, bottleneck areas of materials technology, introduction to the Integrated Computational Materials Engineering (ICME) approach.	5
Module-II	Atomistic schemes in Computational Materials Engineering: Introduction to basics of statistical mechanics, basics of molecular dynamics simulation, application of molecular dynamics for property prediction, basics of Monte Carlo approach and its application for modelling materials properties.	12
Module-III	Prediction of thermodynamic properties of materials: Application of CALPHAD type approaches for prediction of phase diagrams and introduction to recent algorithms using atomistic simulations.	6
Module- IV	Mesoscale methods in materials science: Quantification of microstructure: Application of Monte Carlo and Cellular Automata method for generation of microstructure, Introduction to Phase Field Method and Finite Element Method.	7
Module-V	Basics of Multiscale Modelling involving development of method for improved structure-property correlation: Basics of bridging schemes in multiscale models.	5
Module-VI	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, Optimisation techniques, Evolutionary algorithms.	5

Learning Resources	Computational Materials Engineering: An Introduction to Microstructure Evolution, KGF Janssens, D. Raabe, E. Kozeschnik, M. Miodownik, B. Nestler, Academic Press. Statistical mechanics: A survival guide, A. M. Glazer and J. S. Wark, Oxford University Press. Integrated Computational Materials Engineering (ICME) for Metals: Using multiscale modelling to invigorate engineering design with science, M.E. Horstemeyer, Wiley. Machine Learning, Anuradha Srinivasaraghavan, Vincy Joseph, Wiley. Deep Learning using Python, S. Lovelyn Rose, L. Ashok Kumar, D. Karthika Renuka, Wiley

Course Code	**MM2209**	**Course Name**	**Iron Making**	**Course Category**	Core Theory	L	T	P
						3	0	0

Pre-requisite Courses		**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Introduction: Raw materials used for iron making and their availability in India.Characteristics of suitable raw materials. Blast furnace (BF) iron making- design features of BF and supporting units, viz. Coke ovens, Stoves, gas cleaning systems	6
Module-II	Up gradation of raw materials: Washing of ore & coal; Agglomeration of iron ores – process control and current innovations.	4
Module-III	Reduction mechanism and equilibrium in carbon-oxygen system; slag formation, chemistry and characteristics; Reserve Zones, Cohesive Zone and their importance.	10
Module- IV	Modern trends to minimize coke rate and emissions Injection techniques; Blast furnace (BF) irregularities and remedies. Treatment of slag and outgoing gas.	6
Module-V	Automation and Instrumentation; Treatment of hot metal outside BF.	4
Module-VI	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.	8
Module-VII	Concept of zero CO_2 emission	2

Learning Resources	1. An Introduction to Modern Iron Making - R. H. Tupkary 2. Principles of Blast Furnace Ironmaking: Theory and Practice - A. K. Biswas 3. Ironmaking and Steelmaking: Theory and Practice - Ahindra Ghosh and Amit Chatterjee

Course Code	**MM2274**	**Course Name**	**Extractive Metallurgy Lab.**	**Course Category**	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses	*NIL*	**Co-requisite Courses**	Principles of Extractive Metallurgy	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Assignment on comminution of ore-crushing and grinding circuit, major equipment used, open circuit and close circuit	3
Module-II	Study of design and operation of primary crushing equipment (i) Jaw crusher and (ii) Gyratory crusher	6
Module-III	Study of design and operation of secondary crushing equipment: (i) Roll crusher and (ii) Cone crusher	3
Module- IV	Study of design and operation of grinding equipment - (i) Ball mill	3
Module-V	Study of design and operation of Wilflay table	3
Module-VI	Sieve Analysis of Particles: Plotting of Cumulative Curve	6
Module-VII	Study of kinetics of cementation of copper from aqueous solutions by zinc, and iron	3
Module-VIII	Study of kinetics of leaching of oxide metals in dilute acidic solutions	3

Learning Resources	Process selection in Extractive Metallurgy by Peter Hayes, SBA Pulications Principles of Extractive Metallurgy, Vol.1 by Fathi Habashi, , Gordon and Breach, New York Principles of Mineral Dressing by A. M. Gaudin, McGrew Hill Book Company Mineral Processing by S. K. Jain, CBS publishers and Distributors Pvt. Ltd

Course Code	**MM2275**	**Course Name**	**Heat Treatment Laboratory**	**Course Category**		L	T	P
						0	**0**	**3**

Pre-requisite Courses	Physical Metallurgy of Ferrous Alloys	**Co-requisite Courses**	Heat Treatment	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	**ASTM Standards**

Module	**Syllabus**	**Duration (h)**
Module-I	**Heat Treatment Furnaces** *Types, Construction, Circuit diagram*	3
Module-II	**Operation and Control of Heat Treatment Furnaces**	3
Module-III	**Thermocouple Calibration**	3
Module- IV	**Effect of carbon content (0.3, 0.55, 0.8 and 1.1 wt.%) on microstructure and hardness of plain carbon steels**	3
Module-V	**Effects of cooling rate (annealing, normalizing, oil quenching and water quenching) on microstructure and hardness of eutectoid steel**	3
Module-VI	**Jominy End Quench Test**	3
Module-VII	**Effects of time and temperature on tempering of alloy steels**	3
Module-VIII	**Malleablizing heat treatment of white cast iron**	3
Module-IX	**Heat treatment of high speed steel**	3
Module-X	**Case hardening treatment**	3
Module-XI	**Microstructure and hardness evaluation of TMT rebar**	3
Module-XII	**Viva Voce**	3

Learning Resources	**Testing of Engineering Materials,** H.E. Davis, G.E. Troxell, G.F.W. Hauck, 4th Ed., McGrew Hill. **ASM Handbook Volume 8: Mechanical Testing and Evaluation,** H. Kuhn, D. Medin (Ed.), ASM International. **Practical Non-Destructive Testing,** B. Raj, T. Jayakumar, M. Thavasimuthu, Norasa.

Course Code	MM2276	Course Name	Deformation Behaviour of Materials Laboratory	Course Category	Core Elective	L	T	P
						0	0	3

Pre-requisite Courses	*NIL*	Co-requisite Courses	Deformation Behaviour of Materials	Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-I	Introduction to basics of MATLAB / Python	3
Module-II	Analysis of tensile test data to evaluate elastic modulus, 0.2% yield strength, ultimate tensile strength and fracture strength of metals {using Microsoft Excel / MATLAB / Python}	3
Module-II	Analysis of tensile test data to evaluate strength coefficient, and strain-hardening coefficient, assuming power-law strain-hardening {using Microsoft Excel / MATLAB / Python}	3
Module-III	Analysis of two-dimensional state of stress (plane stress): Transformation of stresses, evaluation of principal stresses, principal directions, maximum shear stress, angle of plane for maximum shear stress; Construction of Mohr's circle of stress – two dimensions {using MATLAB / Python}	3
Module-IV	Analysis of three-dimensional state of stress: Evaluation of invariants of stress, principal normal stresses and corresponding principal directions, principal shear stress, hydrostatic stress, deviatoric stress, J_2 Construction of Mohr's circle of stress – three dimensions {using MATLAB / Python}	3
Module-V	Analysis of three-dimensional state of strain: Evaluation of strain tensor and rotation tensor from a given displacement vector, evaluation of volumetric strain, hydrostatic strain, strain deviator {using MATLAB / Python}	3
Module- VI	Evaluation of elastic strains from elastic stresses and vice-versa for isotropic elastic solids; evaluation of shear modulus and bulk modulus; evaluation of elastic strain energy {using MATLAB / Python}	3
Module-VII	Finite Element simulation of elastic deformation {using COMSOL Multiphysics/ABAQUS}	3
Module- VIII	Evaluation of yielding criteria of ductile metals using Von Mises' and Tresca criteria; Construction of yield locus for a biaxial state of stress	3
Module--IX	Finite Element simulation of elasto-plastic deformation {using COMSOL Multiphysics/ABAQUS}	3
Module-X	Generation of crystal structures and development of understanding of dislocations in various crystal structures (FCC, BCC and HCP). Visualization of dislocations (edge and screw) using ATOMSK code.	3
Module-XI	Study of dislocation-solute interaction in representative alloy systems. Stress fields around dislocation (Volterra dislocations). Study of dislocation stress-field and solute misfit and its ultimate effect on the strength of metallic systems.	6
Module-XII	Viva-Voce	3

Course Code	MM2277	Course Name	Computational Materials Engineering Laboratory	Course Category	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses		Co-requisite Courses	Computational Materials Engineering	Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-I	Introduction to Integrated Computational Materials Engineering for structure-property correlation.	3
Module-II	Introduction to Atomistic Simulation Environment and basics of Python programming.	3
Module-III	Application of statistical mechanics-based tools for determination of thermodynamic properties such as specific heat capacity, enthalpy and free energy.	3
Module- IV	Molecular dynamics of elemental metals and binary alloys to study the phase stability.	3
Module-V	Monte Carlo based microstructure generation-studying grain growth phenomena.	3
Module-VI	Cellular Automata based microstructure design studies.	3
Module-VII	Using COMSOL to simulate any one of the multi-physics phenomena (Induction heating of steel slab, Cooling or solidification of steel, continuous casting, multiscale 3D packed reactor, localised corrosion, anodization of Al).	3
Module-VIII	Using ANSYS to simulate steelmaking processes: Creation of geometry, computational mesh generation, formulation of models, turbulence models, etc.	3
Module-IX	Application of ANSYS to simulate metal forming processes.	3
Module-X	Application for machine learning based approaches for microstructure identification (e.g., Deep Learning approaches in image analysis).	3

Learning Resources	Computational Materials Engineering: An Introduction to Microstructure Evolution, KGF Janssens, D. Raabe, E. Kozeschnik, M. Miodownik, B. Nestler, Academic Press. Statistical mechanics: A survival guide, A. M. Glazer and J. S. Wark, Oxford University Press. Integrated Computational Materials Engineering (ICME) for Metals: Using multiscale modelling to invigorate engineering design with science, M.E. Horstemeyer, Wiley. Machine Learning, Anuradha Srinivasaraghavan, Vincy Joseph, Wiley. Deep Learning using Python, S. Lovelyn Rose, L. Ashok Kumar, D. Karthika Renuka, Wiley

Course Code	**MM3110**	**Course Name**	**Steel Making**	**Course Category**	Core Theory	L	T	P
						3	1	0

Pre-requisite Courses	***Iron making***	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-VII	Steel making: Historical perspective and current scenario; Principles of refining, Steel making in Basic Oxygen Converters, kinetics of reactions; brief overview of various techniques of Top-blown, Bottom-blown and Combined-blown BOF; lance design, slag characteristics	8
Module-VIII	Arc furnace steel making - production of alloy steels; Induction furnace steel making: Use of DRI in steel making.	6
Module-IX	Secondary steel making - Quality, de-oxidation and de-sulphurization; Vacuum techniques- remelting and refining; Injection Metallurgy.	6
Module-X	Inclusion removal and its modification. Casting of ingots and continuous casting. Defects and remedies.	6
Module-XI	Energy and Environmental aspects in steel making, concept of zero CO_2 emission.	4
Module-XII	Latest developments in steel making processes.	4
Module-XIII	Principles of Ferro-alloys production - Application of Submerged Arc furnace; Brief description on production of Ferromanganese, Ferrosilicon, Ferrochrome etc. Application of Thermit reduction process, Preparation of special Ferro-alloys and their applications.	6

Learning Resources	1. An Introduction to Modern Steel Making - R. H. Tupkary 2. Ironmaking and Steelmaking: Theory and Practice - Ahindra Ghosh and Amit Chatterjee

Course Code	MM3111	Course Name	Metal Casting Technology	Course Category	Core Theory	L	T	P
						3	1	0

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	Syllabus	Duration (h)
Module-I	**Introduction**: The features of casting problem; a survey and scope of foundry industry.	3
Module-II	**Solidification**: Review of Solidification of pure metals and al1oys; solidification of actual castings; progressive and directional solidification; centre-line feeding resistance; rate of solidification;	4
Module-III	**Risering**: Riser design; risering curves; NRL method of riser design; feeding distance; risering of complex casting; risering of alloy other than steel; recent developments	3
Module- IV	**Gating**: Gating systems and their characteristics; the effects of gates on aspiration; turbulence and dross trap; recent trends.	4
Module-V	**Patterns**: Pattern design; recent developments in pattern design; materials and construction	5
Module-VI	**Molding and Core Making Processes**: Review and critical comparison of various established processes; recent developments e.g. low pressure and ferrous die casting; high pressure molding; full mold process; flaskless molding, hot and cold box molding;ceramic shell molding; continuous casting; squeeze and pressed casting; Nishiyama process; Shaw process; Anitoch process etc.	8
Module-VII	**Melting**: Selection and control of melting furnaces; moiling, refining and pouring; recent trends in cupola design.	2
Module-VIII	**Fluidity**: Measurement of fluidity; effects of various parameters on fluidity	3
Module-IX	**Internal Stresses, Defects and Surface Finish**: Residual stresses; hot tears and cracks in castings; stress relief; defects and their causes and remedies; various parameters affecting surface finish and related defects e.g. rough Casting, sand bumon sand bumin and metal penetration; facing and washes; mold-wall movement; vapor transpol1 zones; expansion scabbing etc.	7
Module-X	**Testing of Sand**: mulling index; moldability index; compactability; deformability, Universal Strength Measurement (Compression, Shear, Tension); Permeability Test; Moisture Content meaurement; Sieve Aanalysis; Clay Content meaurement	4
Module-XI	**Casting Design Considerations**: Review of casting design; recent trends.	2
Module-XII	**Gases in Metal:** Methods of elimination and control of dissolved gases incastings.	2
Module-XIII	**Inspection and Quality Control:** Reviewof X-ray and gamma ray radiography; magnetic particle; penetrant and ultrasonic inspections; use of statistical quality control in foundry.	3

Learning Resources	Fundamentals of Metal Casting, Flinn, Addison Wesley. Principles of Metal Casting, Heine, Loper & Rosenthal, McGraw Hill. Product Design and Process Engineering Practice, Niebel & Draper, Salmon & Simons, McGraw Hill Foundry, Issac Pitaman. A Textbook of Foundry Technology, O.P. Khanna, Dhanpat Rai Publications Principles of Foundry Technology, P.L. Jain, McGraw Hill Educations

Course Code	**MM3112**	**Course Name**	**Joining of Materials**	**Course Category**	Core Theory	L	T	P
						3	0	0

Pre-requisite Courses		**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Basic Welding Processes, their principles and applications - Gas Welding, Arc Welding, Thermit Welding, Resistance Welding, Spot Welding, Pressure Welding etc.	6
Module-II	Material Joining Techniques - TIG, MIG, Submerged Arc Welding, Electro-slag Welding, Plasma Arc. Welding, Electron Beam Welding, Laser Beam Welding, Ultrasonic Welding, Explosive Welding, Atomic Hydrogen Welding, Under Water Welding, Diffusion Bonding, Friction Stir Welding, Rotary Friction Welding etc., Principles of Brazing, Soldering and joining of dissimilar materials. Additive manufacturing	16
Module-III	Selection of Joining Process; Classification of Electrodes & Weld Joints, Welding Codes, Weld ability of different Materials and their Metallurgical and Mechanical aspects.	6
Module- IV	Physics of Welding - Welding Arc and their types, structure, mechanism, stability and characteristics, Mechanism of Arc blow, its effect and remedies. Types of metal transfer and forces affecting it.	6
Module-V	Defects: Residual stresses and distortion in welded joints and their remedies. Design, Inspection & Testing of weld joints, Economics of joining processes.	6

Learning Resources	Joining of Materials and Structures: From Pragmatic Process to Enabling Technology,Robert W. Messler Jr., Butterworth-Heinemann; 1 edition Welding, D. Greary and Rex Miller, McGraw-Hill Education; 2 edition Welding: Principles and Applications, Larry F. Jeffus, Thomson Delmar Learning, 5th edtion

Course Code	MM3113	Course Name	X-ray Diffraction and Electron Microscopy	Course Category	Core Lab	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	Co-requisite Courses	NIL	Progressive Courses	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	Syllabus	Duration (h)
Module-I	Review of crystal geometry,representation of crystal planes and directions	3
Module-II	Properties of x-rays,continuous and characteristic spectrum, absorption, filters and Bragg's Law, selection of targets	3
Module-III	Fundamentals of x-ray diffraction- Electron-electron interaction, electron-atom interaction, electron-crystal interaction	6
Module-IV	Factors affecting Intensity, Crystal structure indexing, Phase analysis, Spectroscopic analysis, grain size determination, Lattice strain and grain size measurement from x-ray diffraction pattern by single line profile analysis and Hall Williamson method	12
Module-V	Electron Microscopy : Scanning Electron Microscopy, Transmission Electron Microscope – Equipment features, Sample preparation, Electron optics, and imaging, Kikuchi pattern analysis	6
Module-VI	Selected area diffraction pattern (SADP) analysis, Electron dispersive spectroscopy, Electron energy loss spectroscopy	6

Learning Resources	Elements of X-Ray Diffraction - B. D. Cullity and S. R. Stock X-Ray and Electron Diffraction Studies in Materials Science - David Dyson X-Ray Diffraction: A Practical Approach - C. Suryanarayana and M. Grant Norton Electron Diffraction in the Transmission Electron Microscope - P. E. Champness

Course Code	**MM3122**	**Course Name**	**Manufacturing Technology**	**Course Category**	Core Elective-I	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Introduction and Overview of Manufacturing: Materials in manufacturing, Manufacturing processes, Production systems, Trends in Manufacturing	3
Module-II	Glassworking, Shaping processes for Plastics, Rubber processing, Polymer matrix composites	6
Module-III	Powder Metallurgy and Mechanical Alloying: Powder production, Conventional pressing and sintering, Alternative pressing and sintering, Materials and products for powder metallurgy, Mechanical Alloying	12
Module- IV	Machining, Cutting-tool technology, Economy and Product design consideration in machining, Grinding and other abrasive processes, Nontraditional machining and thermal cutting processes	5
Module-V	Processing of Integrated Circuits: Silicon processing, Lithography, Layer Processes used in IC fabrication, Integrating the fabrication steps, IC packaging, Yields in IC processing Micro and Nanofabrication	6
Module-V	Non-equilibrium processing of Materials: Rapid solidification, Laser forming, Bulk amorphous alloy production	4
Module-VI	Advanced manufacturing techniques: Rapid prototyping, Bio-manufacturing (Computer Aided Tissue Engineering Scaffold Fabrication, CAD Assembly Process for Bone Replacement Scaffolds in Computer-Aided Tissue Engineering)	4

Learning Resources	1. Fundamentals of Modern Manufacturing by Mikell P. Groover 2. Non-equilibrium Processing of Materials by C. Suryanarayana 3. Virtual Prototyping and Bio Manufacturing in Medical Applications by Bopaya Bidanda and Paulo Bartolo

Course Code	MM3123	Course Name	Electronic and Magnetic Materials	Course Category	Core Elective-I	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	Co-requisite Courses		Progressive Courses	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-1	**Semiconducting Materials** Fundamentals of band theory and electronic conduction; Intrinsic and extrinsic semiconductors Compound semiconductors Semiconductor devices: Metals-semiconductor contacts, Diode, solar cell, transistors, quantum semiconductor devices, digital circuits and memory devices Semiconductor device fabrication	9
Module-2	**Linear dielectrics** Introduction to dielectric properties of materials Capacitors: ceramic capacitors, non-ceramic capacitors Low, medium, and high-permittivity materials	6
Module-3	**Ferroelectric, Piezoelectric, and Pyroelectric materials** Introduction to Ferro, Piezo, and Pyroelectric behaviour of materials ABO3 structure and ferroelectricity Piezoelectric behaviour of ferroelectrics Devices based on piezoelectrics: expander plate Technologically important piezoelectrics Lead zirconate titanate Pyroelectric materials and devices	11
Module-4	**Magnetic Materials** Introduction to magnetism Diamagnetic, Paramagnetic, Superparamagnetic , Antiferromagnetic, and Ferromagnetic materials Magnetostrction, Magnetocrystalline anisotropy Spinel ferrites, Hexaferrites, Garnets Preparation of ferrites Soft and Hard magnetic materials Magnetic data storage materials: Magnetic hard disks, tapes, MRAMs, CDs and DVDs Inductors and transformers for small signal applications Transformer for power applications Antennas, Microwave devices Magnetooptics	14

Learning Resources	Poplavko, Y., 2018. *Electronic Materials: Principles and Applied Science*. Elsevier. Miller, L.S. and Mullin, J.B. eds., 2012. *Electronic materials: from silicon to organics*. Springer Science & Business Media. Coey, J.M., 2010. *Magnetism and magnetic materials*. Cambridge university press. Jiles, D., 2015. *Introduction to magnetism and magnetic materials*. CRC press.

Course Code	**MM3124**	**Course Name**	**Energy Materials**	**Course Category**	Core Elective	L	T	P
						0	0	3

Pre-requisite Courses	*Physics of Materials*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	**Photovoltaic materials** Basics of photovoltaic conversion: charge excitation, separation, conduction and collection; Crystalline photovoltaics: Silicon solar cells, III-V Multijunction solar cells, Hybrid tandem solar cell; Polycrystalline thin film photovoltaic technology, Perovskite and organic photovoltaic solar cells; Various paradigms of photovoltaic technology and efficiency, Environmental impact of Photovoltaic technology.	7
Module-II	**Battery materials and supercapacitors** Basics: Concepts such as battery potential, charge and figure of merit, energy and power. Thermodynamics of batteries: Electrochemical potential, thermal effects on the electrochemical potential, application of concepts to different materials systems. Interfacial phenomena in battery materials: reversible and irreversible reaction, Butler-Volmer relation, formation of dendrites in battery materials. Electrolytes, separator materials and salts. Li-batteries, Metal-hybrid batteries.	7
Module-II	**Thermoelectric materials** Basic thermoelectric properties: electrical conductivity, thermal conductivity, Seebeck coefficient, lattice thermal conductivity, figure of merit, etc.; Charge carriers, phonons, and scattering mechanisms, influence of composition and microstructure on hermoelectric properties of materials. Example materials such as BiSb, BiCuSeO, SiGe, etc. Application of thermoelectrical materials.	7
Module-III	**Basics of catalysis** Homogenous and heterogenous catalysis, types of catalysts, Photocatalysis, Photocatalytic water splitting, Electrocatalysis	3
Module-IV	**Hydrogen generation and storage** Hydrogen from fossil fuels: Steam reforming, autothermal reforming, methanation, preferential oxidation and water-gas shift reaction, plasma reforming, etc. Hydrogen from renewable sources: pyrolysis and copyrolysis, biomass gasification, thermochemical water splitting, etc. Storage: Physisorption of hydrogen in high-specific area materials, hydrogen intercalation in metals and hydrides.	2
Module-V	**Magnetocalorics** Basic of magnetocaloric effect, thermodynamics and magnetocaloric effect, various magnetocaloric materials such as perovskites, glass composites, alloys, spinel ferrties, etc.	2
Module- VI	**Piezoelectric materials** Basics and genesis of piezoelectricity in materials, natural and synthetic piezoelectric materials, application of piezoelectric materials in sensors, actuators, bio-physical cases and high voltage power sources.	2

Learning resources	C. Honsberg and S. Bowden, Photovoltaics: Devices, Systems, and Applications (PVCDROM) (a free online resource) 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. Modern Magnetic Materials: Principles and Applications, Robert C. O'Handley, Wiley, 2000

Course Code	**MM3178**	**Course Name**	**Metal Casting Technology Laboratory**	**Course Category**	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses	*Physical Metallurgy; Phase Transformations*	**Co-requisite Courses**	Metal Casting Technology	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Orientation: Equipment Layout of Foundry Shop; Introduction to Pattern Shop; Demonstration of Job in Foundry Shop	6
Module-II	Lay-out diagram in Pattern Shop	3
Module-III	Drawing patterns: Drawing (Orthogonal + isometric) in Pattern Shop	3
Module- IV	Pattern-making in pattern shop	3
Module-V	Methoding in Pattern Shop: Gating System & Calculation; Selection of Parting Line	3
Module-VI	Mold Preparation: Practical classes for different types of Jobs in Foundry Shop	6
Module-VII	Core-making in Foundry Shop	3
Module-VIII	Sand Laboratory in Foundry Shop: Universal Strength Measurement (Compression, Shear, Tension); Permeability Test; Moisture Content meaurement; Sieve Aanalysis; Clay Content meaurement	6
Module-IX	Melting and pouring of Metal in Foundry Shop	3
Module-VII	Identification of defects in castings in Foundry Shop	3
Module-VII	Laboratory Viva-voce	3

Learning Resources	"A Textbook of Foundry Technology" by O.P. Khanna, Dhanpat Rai Publications "Principles of Foundry Technology" by P.L. Jain, McGraw Hill Educations

Course Code	**MM3179**	**Course Name**	**Joining of Materials Laboratory**	**Course Category**	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses		**Co-requisite Courses**	**Joining of Materials**	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Visit to the lab and acquaintance with the equipment	3
Module-II	Soldering & brazing with on hand practice	6
Module-III	Gas welding	3
Module- IV	Resistance spot welding	3
Module-V	Manual Metal Arc Welding (MMAW) with on hand practice and spatter loss calculation	6
Module-VI	TIG and MIG welding with on hand practice	6
Module-VII	Submerged Arc Welding	3
Module-VIII	Plasma arc welding for stainless steel and non-ferrous metals and alloys	3
Module-IX	Laboratory Viva-voce	3

Learning Resources	Joining of Materials and Structures: From Pragmatic Process to Enabling Technology, Robert W. Messler Jr., Butterworth-Heinemann; 1 edition Welding, D. Greary and Rex Miller, McGraw-Hill Education; 2 edition Welding: Principles and Applications, Larry F. Jeffus, Thomson Delmar Learning, 5th edtion

Course Code	MM3180	Course Name	X-ray Diffraction and Electron Microscopy laboratory	Course Category	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses	*NIL*	Co-requisite Courses	X-ray Diffraction and Electron Microscopy	Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-I	Demonstration of basic features of x-ray diffractometer and understanding the working principle and operation and calibration of the diffractometer	6
Module-II	Recording and analysis of x-ray patterns of the standard solid samples	6
Module-III	**Analysis of the x-ray diffraction patterns of powder samples Cu, Fe, Zn**	6
Module- IV	**Crystal structure indexing and determination of precise lattice parameter and density**	6
Module-V	**Grain size determination of nanocrystalline materials**	3
Module-VI	Analysis of XRD patterns of as cast, mechanically worked and heat-treated samples	6
Module-VII	Make up laboratory classes	6
Module-VIII	Viva-voce	3

Learning Resources	1. Elements of X-Ray Diffraction - B. D. Cullity and S. R. Stock 2. X-Ray and Electron Diffraction Studies in Materials Science - David Dyson 3. X-Ray Diffraction: A Practical Approach - C. Suryanarayana and M. Grant Norton 4. Electron Diffraction in the Transmission Electron Microscope - P. E. Champness

Course Code	MM3214	Course Name	Mechanical Testing of Materials	Course Category	Core Theory	L	T	P
						4	**0**	**0**

Pre-requisite Courses	Deformation Behaviour of Materials	Co-requisite Courses	*Nil*	Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-I	**Introduction:** Mechanical behaviour of solids, Material properties and their classifications, Importance of testing of materials.	2
Module-II	**Hardness:** Classification, Scratch hardness, Mohs scale, Rebound hardness, Shore's Scleroscope, Indentation hardness - Principles and Practices of Brinell, Vickers, Knoop, Rockwell, Meyer hardness testing; Macro- and micro-hardness; Nanoindentation; Oliver-Pharr method; Comparison of various indenters; Indentation Size Effect; Indentation Fracture Toughness; Relationships between hardness and strength.	8
Module-III	**Tensile:** Elastic, anelastic and plastic properties of materials; Tensile properties; Engineering and true stress-strain diagrams; Plastic instability; Factors affect stress-strain response; The relations between stress, strain, strain rate and temperature of engineering materials; Superplasticity; Types of failure; Ductile and brittle fracture; Transgranular and Intergranular fracture; Micromechanisms of failure.	6
Module- IV	**Compression, Torsion and Bending:** Mechanical properties in compression, torsion and bending; Stresses at large plastic stress; Compression tests; Solid and Tubular torsional tests; Shear stress-shear strain; 3-point and 4-point bending tests; Bending strength; Types of failure; Hot deformation.	6
Module-V	**Impact:** Effects of strain rate on mechanical properties; Not-bar impact tests -Charpy and Izod; Instrumented Charpy; Various transition temperatures and their significance; Effects of metallurgical factors on transition temperature; Drop weight test.	4
Module-VI	**Fatigue:** Importance; Dynamic loading; Classification of high cycle and low cycle fatigue; The S-N curve; Statistical nature of fatigue; Effects of mean stress, stress range and notch; Criteria of fatigue failure; Design for fatigue; Cyclic stress-strain curve; Strain-life equation; Factors influencing fatigue properties; Features of fatigue failure; Initiation fatigue crack, Different stages of fatigue crack propagation; Paris' law; Improvement of fatigue strength via controlling of metallurgical variables.	6
Module-VII	**Creep:** Deformation at elevated temperature; Creep curve; Effects of temperature and stress; Mechanisms of creep deformation; Deformation mechanisms map; Stress rapture test; Design of creep resistance materials	6
Module-VIII	**Non-destructive testing:** Introduction to assessment of mechanical properties by non-destructive testing methods	2

Learning Resources	**1. Testing of Engineering Materials,** H.E. Davis, G.E. Troxell, G.F.W. Hauck, 4th Ed., McGrew Hill. **2. Mechanical Metallurgy,** G.E. Dieter, 3rd Ed, McGraw Hill. **3. ASM Handbook Volume 8: Mechanical Testing and Evaluation, H. Kuhn, D. Medin (Ed.),** ASM International. **4. Practical Non-Destructive Testing,** B. Raj, T. Jayakumar, M. Thavasimuthu, Norasa. **5. Mechanical Behavior and Testing of Materials,** A.K. Bhargava, PHI Pub., 2011. **6. Testing of Metallic Materials,** A.V.K. Suryanarayana, 2nd Ed., BS Publications.

Course Code	**MM3215**	**Course Name**	**Alloy Steels and Cast Iron**	**Course Category**	Core Theory	L	T	P
						4	0	0

Pre-requisite Courses		**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Effect of allying elements on the structure and properties of steel. Solubility and diffusivity of solute atoms in iron-based systems.	6
Module-II	Stainless steels: Classification and Properties	2
Module- III	Evolution of microstructures in low and high alloy steels. Effect of multiphase microstructure on the mechanical properties of steel. + Tool Steel + High Speed Steel + Dual Phase Steel, HSLA steels, Bainitic steels, IF steels, TRIP steel, TWIP steel, CP steel,	5
Module-IV	Physical metallurgy of new generation steels – ultra low carbon steels, precipitation hardenable steels, steels inheriting transformation induced plasticity, high strength low alloy steels, Ultra high strength steels.	8
Module-V	Emerging steels for off shore and on shore applications. Theories for improvement of time dependent properties of steels.	6
Module-VI	Alloying of cast iron - its influence on the microstructures, Effect of microstructures on the properties of alloy cast iron. Austempered ductile iron, its processing-structure-property correlation, emerging alloy cast iron of varying morphology of graphite.	7

Learning Resources	Alloy Steel: Properties and Use, Leroy Sydney, Scitus Academics LLC, 2016 Cast Iron: Physical and Engineering Properties, By H. T. Angus, Butterworths, 2nd edition

Course Code	**MM3216**	**Course Name**	**Physical Metallurgy of Non-Ferrous Alloys**	**Course Category**	Core Theory	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Elements of physical metallurgy of non-ferrous metals-classification, order-disorder transformation, spinodal decomposition, massive transformation	6
Module-II	Phase diagram, heat-treatment, microstructure, physical, chemical and mechanical properties of aluminium alloys	5
Module-III	Phase diagram, heat -treatment, microstructure, physical, chemical and mechanical properties of copper alloys	5
Module- IV	Phase diagram, heat -treatment, microstructure, physical, chemical and mechanical properties of magnesium alloys	5
Module-V	Phase diagram, heat -treatment, microstructure, physical, chemical and mechanical properties of zinc alloys and nickel alloys	5
Module-V	Phase diagram, heat -treatment, microstructure, physical, chemical and mechanical properties of titanium alloys	5
Module-VI	Phase diagram, heat -treatment, microstructure, physical, chemical and mechanical properties of gold, silver, and rare earths.	5
Module-VI	Non-ferrous alloys for high temperature applications	2

Learning Resources	Introduction to Physical Metallurgy, Sidney H. Avner, Tata-McGraw-Hill Education, 2nd edition Light Alloys: Metallurgy of the light metals, 5th edition, By Ian Polmear, David StJohn, Jian-Feng Nie, Ma Qian, Butterworth-Heinemann Engineering Properties of Nickel and nickel alloys, John L. Everhart, Plenum Press

Course Code	MM3217	Course Name	Materials Characterization	Course Category	Core Lab	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	Co-requisite Courses		Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-I	Advanced optical microscopic techniques: Interference and polarized ray microscopy, Near Scanning Optical filed Microscopy, Confocal Microscopy	6
Module-II	Principles and application of Auger Electron spectroscopy	2
Module- III	Thermal Analysis techniques : DTA-TGA, DSC, Dilatometry and DMA	6
Module-IV	Magnetic Materials and their characterization techniques	6
Module-V	Characterization of materials by electrical methods	6
Module-VI	Scanning probe microscopy : STM, AFM and MFM	6

Learning Resources	1. Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC press, 2008 2. Concise Encyclopedia of Materials Characterization, Edited by Robert W Cahn, and Eric Lifshin, Pergamon press 1998

Course Code	MM3218	Course Name	Metal Forming Technology	Course Category	Core Theory	L	T	P
						3	**0**	**0**

Pre-requisite Courses	*Deformation Behaviour of Materials*	Co-requisite Courses	Nil	Progressive Courses	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		Data Book / Codes/Standards	

Module	Syllabus	Duration (h)
Module-I	**Introduction to Metal Forming:** Introduction; Importance of metal working; Review of mechanisms of plastic deformation; Stress-strain relationships; Yield criteria and their significance; Concept of flow stresses; Metallurgical aspects of metal forming; Hot, warm and cold working processes.	6
Module-II	**Fundamental to Metal Forming:** Classification of forming processes; Advantages and Limitations; Mechanics of metal working; Effects of temperature, strain rate, microstructure, friction and lubrication in metal forming; Determination of flow stress for metal working; Workability; Role of hydrostatic pressure; Residual stress;	8
Module-III	**Forging:** Introduction and Classification; Operation and principle of Forging Processes and Equipment, Methods of forging, Open and Close Die Forging Processes, Defects, Structure and Properties of Forged Products; Force Analysis in forging.	6
Module- IV	**Rolling:** Introduction and Classification; Types of Rolling Mills; Forces and Geometrical Relationships in Rolling, Calculation of Rolling Load, Roll Pass Design, Defects in Rolled Products; Rolling mill control and automation.	6
Module-V	**Extrusion:** Introduction and Classification; Extrusion Equipment; Forces in extrusion; Analysis of Extrusion Process, Extrusion of components including Seamless Pipes and Tubes; Extrusion of pipes by cold working; Impact Extrusion, Hydrostatic Extrusion; Defects in extruded products.	4
Module-VI	**Drawing:** Introduction and Classification; Wire Drawing, Rod Drawing, Tube Drawing, Deep Drawing, Analysis of Wire Drawing Process and Load Calculations, Tube drawing; Defects and remedies.	4
Module-VI	**Sheet Metal Forming:** Principle, process parameters, equipment and application of the following processes: shearing, spinning, stretch forming, blanking, bending etc. Explosive forming, Hydro forming, electro hydraulic forming, and magnetic pulse forming. High Velocity forming of metals and High energy Rate forming.	6

Learning Resources	
	Mechanical Metallurgy, G. E. Dieter, McGraw Hill, New Delhi **Mechanical Working of Metals-Theory and Practice,** PJ.N. Harris, Pergamon Press **Metal Forming: Mechanics and Metallurgy,** W.F. Hosford and R. M. Caddell, Prentice-Hall **Principles Industrial Metalworking Processes,** G.W. Rowe, CBS Publishers & Distributors **Fundamental of Metal Forming Processes,** B.L. Juneja, New Age Int. Publ

Course Code	**MM3281**	**Course Name**	**Mechanical Testing Laboratory**	**Course Category**	Core Lab	L	T	P
						0	**0**	**3**

Pre-requisite Courses	Nil	**Co-requisite Courses**	Mechanical Testing of Materials	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	**ASTM Standards**

Module	**Syllabus**	**Duration (h)**
Module-I	**Introduction, Orientation, sampling and Testing Standards**	3
Module-II	**Indentation hardness testing - I** Brinell, Rockwell, Meyer, Vicker and Knoop hardness testing	3
Module-III	**Indentation hardness testing - II** Brinell, Rockwell, Meyer, Vicker and Knoop hardness testing	3
Module- IV	**Microhardness Testing**	3
Module-V	**Nano-hardness and nano-scratch testing**	3
Module-VI	**Tensile and Compression Testing**	3
Module-VII	**Torsion and 3-Point Bending testing**	3
Module-VIII	**Charpy and Izod Impact Testing**	3
Module-IX	**Fatigue testing and S-N curve.**	3
Module-X	**Nondestructive testing-I** Visual inspection, liquid penetrant, magnetic particle, ultrasonic, acoustic emission, Eddy current testing etc.	3
Module-XI	**Nondestructive testing-II** Visual inspection, liquid penetrant, magnetic particle, ultrasonic, acoustic emission, Eddy current testing etc.	3
Module-XII	**Viva Voce**	3

Learning Resources	**Testing of Engineering Materials,** H.E. Davis, G.E. Troxell, G.F.W. Hauck, 4th Ed., McGrew Hill. **ASM Handbook Volume 8: Mechanical Testing and Evaluation,** H. Kuhn, D. Medin (Ed.), ASM International. **Practical Non-Destructive Testing,** B. Raj, T. Jayakumar, M. Thavasimuthu, Norasa.

Course Code	MM3282	Course Name	Material Processing Lab	Course Category	Core Lab	L	T	P
						0	**0**	**3**

Pre-requisite Courses		Co-requisite Courses	Mechanical Testing of Materials	Progressive Courses	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	**ASTM Standards**

Module	Syllabus	Duration (h)
Module-I	**Melting of ferrous and non-ferrous metals and alloys**	3
Module-II	**Assessment of Formability (Erichsen Cupping Test)**	3
Module-III	**Rolling (Hot and Cold rolling) of Metals**	3
Module- IV	**Powder Metallurgical Processing; Microstructure analysis of Bearings and Filters**	18
Module-V	**Physical and Mathematical modelling of metal working: Computational approach**	3
Module-VI	**Introduction to Composite Processing and Microstructure analysis**	3
Module-VII	**Additive Manufacturing: Introduction to 3D priting of CAD models**	3
Module-VIII	**Thin Film Deposition: Creating and depositing thin film coatings on substrate material**	6

Learning Resources	G.A. Higgerson, Experiments in Materials Technology, Affiliated East-West Press, 1973. G.E. Dieter, Mechanical Metallurgy, McGraw-Hill, 3rd Ed., 1988. Lorraine Francis, Materials Processing 1st Edition: A Unified Approach to Processing of Metals, Ceramics and Polymers, 2015, ISBN: 9780123851338.

Course Code	MM3283	Course Name	Materials Characterization Laboratory	Course Category	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses	*NIL*	Co-requisite Courses	Materials Characterizaton	Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-I	Determination of grain size and lattice strain from X-ray diffraction pattern by single line profile analysis and Williamson Hall method + XRD of powder + crystal structure	3
Module-II	Study of the phase transformation and its kinetics by DTA-TGA and DSC techniques	6
Module-III	Study of microstructure, surface topography using SEM-SEI and BSE modes and determination of chemical composition of the phases using SEM -EDS facilities	6
Module- IV	Characterization of materials by electrical resistivity measurements	3
Module-V	Studying the microstructure and topography with the aid of AFM in contact, noncontact and tapping mode	6
Module-VI	Analysis of TEM microstructural images and SAD patterns	3
Module-VII	Make up laboratory classes	3
Module-VIII	Viva voce	3

Learning Resources	Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC press, 2008 Concise Encyclopedia of Materials Characterization, Edited by: Robert W Cahn, and Eric Lifshin, Pergamon press 1998

Course Code	**MM4119**	**Course Name**	**Ceramic and Composite Materials**	**Course Category**	Core Theory	L	T	P
						3	0	0

Pre-requisite Courses		**Co-requisite Courses**		*NIL*	**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*	

Module	**Syllabus**	**Duration (h)**
Module-I	Ceramic Materials: Introduction to ceramics as engineering materials, Common crystal structures in ceramics; Silicates, clay, minerals, graphite and carbides, structure of glasses. Imperfections in ceramics,Classification of ceramics and their applications; Ceramic raw materials and their characterization, Raw material preparation and processing of ceramics, Casting processes like drain casting, tape casting etc. Properties of ceramic powder particle-size, shape and surface properties. Flocculation and rheology.	8
Module-II	Phase diagrams and phase transformation in ceramic material. Forming Processes: Extrusion, Pressing, Injection Moulding.	4
Module-III	Mechanical behavior of structural ceramics-brittleness and its improvement, Different toughness measuring techniques. Significance of Fracture toughness, elastic modulus and strength of structural ceramics. Electrical, magnetic and optical properties of important ceramic systems.	6
Module- IV	Functional ceramics diverse application in cutting tool, mobile phone microwave devices polycrystalline diamond and solid oxides for fuel cells, Introduction to electro active ceramics and bio-ceramics	6
Module-V	Composite Materials: Classification of composite materials. Dispersion strengthened, particle reinforced and fiber reinforced composites, Mechanics and strengthening mechanisms in composite materials. Properties of composites: Elastic Properties, Strength and toughness.	6
Module-VI	Design of composites; In-situ and ex-situ composites; Interfaces between reinforcements and matrices in composites; Bonding Mechanisms, Bond Strength, Interfacial Toughness.	6
Module-VII	Polymer Matrix Composites: Polymer Matrices, Processing Techniques, Glass Reinforced Plastics, Carbon Fiber Composites; Metal matrix Composites; Metal Matrices, Processing Techniques, Interfacial Controls, Discontinuously Reinforced Composites, Fiber Composites; Ceramic Matrix Composites: Ceramic Matrices, Processing Techniques, Alumina Matrix Composites, Glass Matrix Composites, Nanocomposites and its usefulness.	8

Learning Resources	1. Fundamentals of Ceramics, M.W Barsoum, Taylor and Francis 2. An Introduction to Composite Materials, By D. Hull, T. W. Clyne, Cambridge University Press 3. Ceramic-Matrix Composites: Microstructure, Properties and Applications, edited by I M Low, CRC Press

Course Code	**MM4120**	**Course Name**	**Degradation of Materials**	**Course Category**	Core Theory	L	T	P
						3	0	0

Pre-requisite Courses		**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*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-VIII	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

Learning Resources	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 A.S. Khanna, Introduction to High Temperature Oxidation and Corrosion, ASM International, Materials Park, Ohio

Course Code	**MM4125**	**Course Name**	**Powder Metallurgy**	**Course Category**	Core Elective II	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Development and scope of powder metallurgy; Different metal powder production (mechanical methods and physic-chemical and chemical methods) viz. crushing, grinding, milling, atomization, reduction, electrolysis, carbonyls etc.	6
Module-II	Characterization of metal powders- chemical compositions, structure, shape, size and their determination, powder flow, apparent density, tap density, compressibility and porosity measurements; powder conditioning and treatments	8
Module-III	Behavior of metal powders during compaction. Different compaction techniques like dicompaction, isostatic pressing, powder rolling, powder extrusion etc. Types of presses, tooling and die design	10
Module- IV	Mechanism of theory of sintering of single component powders, sintering of mixed powders and composites, liquid phase sintering, reactive sintering, activated sintering, sintering furnaces and atmosphere etc	10
Module-V	Application: production and usage of powder metallurgy products viz. cemented carbides, porous parts, structural parts, dispersion strengthened materials, aerospace applications etc	6

Learning Resources	R.M. German, Powder Metallurgy Science, 2nd ed. John Wiley, 1999. A. Upadhyaya, G.S. Upadhyaya, Powder Metallurgy: Science, Technology and Materias, 2011 ASM Handbook, Volume 7: Powder Metal Technologies & Applications (1998)

Course Code	**MM4126**	**Course Name**	**Stainless Steel**	**Course Category**	Core Elective-II	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	**Overview of Stainless Steel**: a. What is Stainless Steel? b. Alloying elements in Stainless Steel and their functions. c. Impact of alloying elements on properties of Stainless Steel d. Major grades of Stainless Steel e. Cost implications of alloy addition and substitutes	4
Module-II	**Phase transformations in Stainless Steel**: a. Relevance of Nickel equivalent and Chromium equivalent b. Why Fe-C diagram is inadequate for Stainless Steel? c. Role of alloying elements in ferrite and austenite stabilisation d. Role of deformation induced transformation	5
Module-III	**Stainless Steel (SS) making and processing**: a. Complete overview covering Electric Arc Furnace, Argon oxygen decarburisation, Ladle Refining, Vacuum Oxygen Decarburisation, Vacuum degassing, Ingot casting vis-à-vis Continuous casting, Hot Rolling, Annealing and Pickling, Cold Rolling, Final Annealing and Pickling, Skin Pass Mill, Strip Grinding Line b. Various Finishes in Stainless Steel c. Colour Coating of Stainless Steel	8
Module- IV	**Stainless Steel fabrication:** a. Cold roll forming (CRF) process mechanism b. Cutting of Stainless Steel c. Welding of Stainless Steel i. Sensitization/Weld decay: Causes, mechanisms, remedies 1. High temperature sensitization 2. 475 C embrittlement 3. α' phase transformation ii. Distortion: Causes, mechanisms, remedies iii. Effect of alloying elements on weldability of SS: 1 Schaeffler De Long diagram interpretations d. Tools and Equipment e. Issues faced during fabrication of stainless steel and their Solutions	4
Module-V	**Corrosion in Stainless Steel:** a. Major types of corrosion b. Galvanic corrosion: Mechanism and prevention c. Pitting Corrosion: Mechanism and prevention, Interpretation of PREN d. Crack propagation mechanisms i. Inter-granularii. Trans-granular	5
Module-VI	**Testing, Handling and Storage of Stainless steel:** a. PMI technique b. Other NDT methods c. Recommended procedures for storage	2
Module-VII	**Applications of Stainless Steel in various Segments:** a. Automotive, Railways & Transport b. Architecture, Building & Construction c. Reinforcement bars d. Roofing sheets e. Material Handling applications f. Process Industries g. Life Cycle Cost Analysis	6
Module-VIII	**Plant visit for students:** a. Hisar or Jajpur	8

Learning Resources	Stainless Steels, edited by J. R. Davis, ASM Handbook Duplex Stainless Steels: Microstructure, Properties and Applications, edited by R Gunn, Abington Publishing

Course Code	**MM4127**	**Course Name**	**Polymeric Materials**	**Course Category**	Core Elective-II	L	T	P
						3	0	0

Pre-requisite Courses	*Materials Characterization*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Classification of polymers: Basic definitions and nomenclature	4
Module-II	Synthesis of polymers: Classification of polymerization	4
Module-III	Phase structure and morphology of polymers: Amorphous state, glass transition, crystalline state, polymer blends	8
Module- IV	Mechanical and thermomechanical characteristics of polymers: Elastic deformation, models of viscolesticty, deformation of elastomers, yielding and crazing, fracture	8
Module-V	Polymer nanocomposites: synthesis, characterization of structure, mechanical and thermal properties	8
Module-VI	Prediction of physical properties of nanocomposites	8

Learning Resources	Robert J. Young, and Peter A. Lovell, Introduction to Polymers, CRC Press, 3rd edition 2011. Joseph H. Koo, Polymer Nanocomposites: Processing, Characterization, and Applications, McGraw-Hill 2006.

Course Code	MM4184	Course Name	Ceramic and Composite Materials Lab.	Course Category	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses		Co-requisite Courses		Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-I	Visit to the lab and acquaintance with the equipment	3
Module-II	Preparation of metal matrix composite	3
Module-III	Metallographic and mechanical properties study of different composite materials	18
Module- IV	Metallographic and mechanical properties study of different ceramic materials	12
Module-V	Repeat process	3
Module-VI	Laboratory Viva-voce	3

Learning Resources	Fundamentals of Ceramics, M.W Barsoum, Taylor and Francis An Introduction to Composite Materials, By D. Hull, T. W. Clyne, Cambridge University Press Ceramic-Matrix Composites: Microstructure, Properties and Applications, edited by I M Low, CRC Press Metal Matrix Composites, Nikhilesh Chawla, Krishan K. Chawla, 2nd edition Springer

Course Code	**MM4185**	**Course Name**	**Degradation of Materials Laboratory**	**Course Category**	Core Lab	L	T	P
						0	0	3

Pre-requisite Courses		**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Corrosion rate measurement by immersion test methods in various media (acidic and basic)	
	(a) Structural steels	3
	(b) Pipeline steels	3
	(c) Automobile car body materials	3
	(d) Bio materials	3
Module-II	Polarization study in acid and basic media	
	(a) Metallic Materials (Structural materials, Pipeline steel, Bio materials)	9
	(b) Composite materials (aluminium metal matrix)	3
	(c) Ceramic materials	3
	(d) Polymer materials	3
Module-III	Open Circuit Potential, Potentiostatic, Potentiodynamic measurement using inhibitors in acid and basic media for metallic materials	6
Module-IV	Oxidation rate measurement at different temperatures of Pure metal and Alloys	3
Module-V	Wear rate measurement by pin and disc method for different steels and ceramics materials	6

Learning Resources	
	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
	A.S. Khanna, Introduction to High Temperature Oxidation and Corrosion, ASM International, Materials Park, Ohio

Course Code	**MM4221**	**Course Name**	**Design and Selection of Materials**	**Course Category**	Core Theory	L	T	P
						3	1	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Introduction to metals & alloys, polymers, ceramics and composites, Properties of materials and their evaluations	10
Module-II	Material property charts: Modulus-Density, Strength-Density, Modulus-Strength, Fracture toughness-Modulus, Thermal conductivity-Resistivity, Wear rate-Hardness,Thermal expansion-Modulus of elasticity.	6
Module-III	Material selection strategy, flow of material selection procedure	4
Module- IV	Case studies of material selections: Materials for springs, Elastic hinges, Safe pressure vessels, Damping material for shaker table, Material for solar heating, energy efficient kiln walls, Materials forheat exchangers	6
Module-V	Classification of processes, Shaping, Joining and Machining, Systematic process selection	4

Learning Resources	Materials Selection in Mechanical Design, Michael F. Ashby

Course Code	**MM4228**	**Course Name**	**Fracture and Failure Analysis**	**Course Category**	Core Elective	L	T	P
						3	0	0

Pre-requisite Courses		**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Introduction to fractography: Identification of different types of fracture	4
Module-II	Linear Elastic Fracture Mechanics: Estimation of theoretical cohesive strength of brittle materials, Griffith's criterion and equations for plane stress and plane strain, Orowan's and Irwin's equations, Concept of strain energy release rate, Concept of modes of deformation, Concept of stress intensity factor, K_I singularity, plasticity considerations, K_{IC}, CTOD, resistance curves, plane-stress analyses;	12
Module-III	Interfacial Fracture Mechanics: theory, crack-path considerations; sub critical crack growth;	4
Module- IV	Nonlinear Elastic Fracture Mechanics: HRR singularity, J_{IC}, J_R (⍰a) resistance curves, T_R, CTOA, non-stationary crack-growth analysis.	12
Module-V	Environmentally-Assisted Fracture; stress corrosion, hydrogen embrittlement, corrosion fatigue, Cyclic Fatigue Failure: mechanistic aspects, crack propagation, damage-tolerant analysis, variable amplitude loading small cracks, crack closure, stress-strain/ life analysis.	6
Module-VI	Physical Basis of Toughness: intrinsic toughening - metals, extrinsic toughening - ceramics, composites, Fracture statistics.	4

Learning Resources	G.E. Dieter: Mechanical metallurgy, McGraw Hill Book Company, New Delhi, 1986. R.W. Hertzberg, R. P. Vinci, and J. L. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, Wiley, 5th edition.

Course Code	**MM4229**	**Course Name**	**Thin Films and Coatings**	**Course Category**	Core Elective	L	T	P
						3	0	0

Pre-requisite Courses		**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module I	**Introduction** Conventional Surface Engineering, Types of Surface Modifications, Physical Modifications, Chemical Modifications, 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	05
Module III	**Thin-film Evaporation Processes** Physics and Chemistry of Evaporation, Film Thickness Uniformity, Evaporation Processes and Applications, Thermal Evaporation, E-beam evaporation, Case studies.	07
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, Case studies.	07
Module V	**Chemical Vapor Deposition** Reaction types, Thermodynamics of CVD, Gas transport, Film growth kinetics, Thermal CVD, Plasma-enhanced CVD, Case Studies.	07
Module VI	**Substrate Surface and Thin-film Nucleation** Atomic view of substrate surface, Thermodynamic aspects of nucleation, Kinetic processes in nucleation and growth	05

Learning Resources	Milton Ohring, Materials Science of Thin Films, 2nd edition, Academic Press

Course Code	**MM4230**	**Course Name**	**Non-destructive Characterization**	**Course Category**	Core Elective I	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*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.	3
Module-II	**Visual examination**: Methods. Different visual examination aids.	2
Module-III	**Leak and pressure testing of industrial components**: Various methods of pressure and leak testing underlying principles of these testing systems.	3
Module- IV	**Dye penetrant method**: Liquid penetrant testing – procedure; penetrant testing materials, penetrant testing method – sensitivity; application and limitations.	4
Module-V	**Magnetic particle testing**: Definition and principle; magnetizing technique, procedure, equipment, sensitivity and limitations.	4
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.	10
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.	6
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.	6

Learning Resources	1. A. V. K. Suryanarayana: Testing of Metallic Materials. PHI Pub. 2. Baldev Raj, T. Jayakumar, M. Thavasimuthu: Practical Non-Destructive Testing. Narosa Pub. House. 3. Ravi Prakash: Non-Destructive Testing Techniques. New Age International Pub.

	4. ASM Metals Handbook (Vol. 17): Non-Destructive Evaluation of Materials. American Society of Metals, Metals Park, Ohio, USA. 5. Paul E. Mix: Introduction to Non-destructive Testing: A Training Guide. Wiley Pub.

Course Code	**MM4261**	**Course Name**	**Nanomaterials**	**Course Category**	Core Elective	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Introduction to Nanoscience and Nanotechnology.	2
Module-II	Classification of nanomaterials	3
Module-III	Underlying physical principles of nanotechnology: Nanostructured Materials,Fundamental physicochemical principles underlying the size dependence of the properties of nanostructured matter.	9
Module- IV	Characterization of nanomaterials	3
Module-V	Top down and bottom up approaches to building nanostructured materials.	9
Module-VI	Carbon nanostructures, Fullerenes, CNT and graphene	9
Module-VII	Application of nanomaterials in daily life, information technology and healthcare	3

Learning Resources	1. Dieter Vollath, Nanomaterials An Introduction to Synthesis, Properties, and Applications, Wiley-VCH, 2013 2. Rajendra Kumar Goyal, Nanomaterials and Nanocomposites: Synthesis, Properties, Characterization Techniques, and Applications, Taylor and Francis, 2017 3. Guozhong Cao: Nanostructures Nanomaterials: Synthesis properties & applications. Imperial College Press.2004

Course Code	MM4262	Course Name	Biomaterials	Course Category	Core Elecetive	L	T	P
						3	0	0

Pre-requisite Courses	*NIL*	Co-requisite Courses		Progressive Courses	*NIL*
Course Offering Department		*Metallurgy and Materials Engineering*		Data Book / Codes/Standards	*NIL*

Module	Syllabus	Duration (h)
Module-I	**Basics:**Materials and Biology: Metal, Ceramic, Polymer, Composite; Bioresorbale and bioerodable materials	4
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	8
Module-III	**Testing of biomaterials:** In vitro and in vivo assessment; evaluation of blood material interactions; Microscopic techniques; Spectorscopic Techniques	6
Module- IV	**Degradation of Materials:** Degradation of polymers; Degradation effect on metals and ceramics	4
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	4

Learning Resources	1. Ratner, Buddy D., et al. Biomaterials Science: An Introduction to Materials in Medicine 2. 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	**MM4263**	**Course Name**	**Engineering Composite Materials**	**Course Category**	Open Elective	L	T	P
						3	0	0

Pre-requisite Courses	*Deformation Behaviour of Materials*	**Co-requisite Courses**		**Progressive Courses**	*NIL*
Course Offering Department		***Metallurgy and Materials Engineering***		**Data Book / Codes/Standards**	*NIL*

Module	**Syllabus**	**Duration (h)**
Module-I	Introduction and classification of composites, Manufacturing of composites	2
Module-II	**Review of stress and strain**: Sign conventions;Strain in 2D; Stress-strain relations for plane stress; On-axis stress-strain relations	4
Module-III	**Stress-strain and Material Property Transformations**: Transfromation of stresses; Mohr's circle construction;Transformation of strain	8
Module- IV	**Off-axis stiffness of unidirectional composites:** Determination of off-axis compliance;	6
Module-V	**Micromechanical analysis of Composite Strength and Stiffness**: Basic assumptions of micromechanics; longitudinal strength and stiffness; derivation of transverse modulus	6
Module-VI	**Symmetric Laminates**: Evaluation of in-plane stiffness; Evaluation of Flexural Stiffness; Symmetric Cross-ply Laminates	8
Module-VII	**Properties of General Laminates**: Anti-symmetric Laminates; Unsymmetric Cross-Ply Laminates	8

Learning Resources	1. Stephen W. Tsai and H. Thomas Hahn, Introduction to Composite Materials, Technomic Publishing Co, Inc.; 1st edition, 1980 2. Robert R. Jones, Mechanics of Composite Materials, CRC press, 1998 3.Mathews F.L. and Rawlings R.D., Composite materials: Engineering and Science, Chapman and Hall, London, England, 1st edition, 1994. 4. Chawla K.K., Composite materials,Springer, Verlag, 2006.