Indian Institute of Technology Kanpur

COURSES OF STUDY

2024

Indian Institute of Technology Kanpur

KANPUR-208016

MATERIALS SCIENCE AND ENGINEERING

1. B.Tech. Template (BT)

	Semester							
	1st	2nd	3rd	4th	5th	6th	7th	8th
Courses	SCHEME-1 [9] ELC111/ELC112/ELC113 or ETH111[3]	ETH111[3] or SCHEME-1 [9] ELC111/ELC112 /ELC113	SCHEME-2 EME (9-11)	SCHEME-3 HSS-1 (9-11)		SCHEME HSS-II (9)	SCHEME HSS-II (9)	SCHEME HSS-II (9)
	MTH111[6] / MTH113[6]	MTH113[6] / MTH111[6]	ESO202 (11)	ESC201 (14)	MSE301 (9)	ESO Basket (6-11)+	DE-3 (9)	OE-3 (9)
	MTH112[6] / MTH114[6]	MTH114[6] / MTH112[6]	ESO225 (8)	MSE202 (11)	MSE302 (9)	MSE 306* (9)	DE-4 (9)	OE-4 (9)
	PHY114[11]	PHY113[11]	MSE201 (11)	MSE203 (11)	MSE303 (9)	DE-1 (9)	OE-1 (9)	OE-5 (9)
	PHY111 [3] / CHM111[3]	CHM111[3] / PHY111 [3]	MSE204 (9)	MSE205 (8)	MSE304 (9)	DE-2 (9)	OE-2 (9)	OE-6 (6-9)
	TA111[9] / ESC111[7]	ESC111[7] / TA111[9]			MSE305 (9)			
	CHM112[4] / ESC112[7]	ESC112[7] / CHM112[4]						
	CHM113[4] / LIF111[6]	LIF111 [6] / CHM113[4]	TA211 (3)		MSE351 (3)	MSE353 (3)		
	PE111[3] / PE112[3]	PE112[3] / PE111[3]	TA212 (3)	MSE251 (3)	MSE352 (3)	MSE360 (6)		
Credits	55/52	52/55	54-56	56-58	51	51-56	45	42-45

UGP-1 (MSE396) (4 credits) and UGP-4 (MSE498) are optional (over and above the minimum credit requirements)
UGP-2 (MSE496) (9 credits) can be taken in lieu of one DE course
UGP-3 (MSE497) (9 credits) can be taken in lieu of one OE course
+ESO Basket: ESO207/ MSO201/ HSO201/ MSO203M (One course required)

Credit required for graduation

Course Type	MSE template
Institute Core (IC)	112
SCHEME	54-58
E/SO	31-36
DC + DE	158
Open Electives (OE)	51-54

Total	406-418

2. B.Tech.-Honours (BTH) template

Courses for Semester-1 and 2 are same as in the template for B.Tech. (Template at entry No. 1)

	semester					
	3rd	4th	5th	6th	7th	8th
Courses	SCHEME-2 (9-11)	SCHEME-3 HSS-1 (9-11)		SCHEME HSS-II (9)	SCHEME HSS-II (9)	SCHEME HSS-II (9)
	ESO202 (11)	ESC201 (14)	MSE301 (9)	ESO Basket (6-11)+	UGP-2* (9)	UGP-3* (9)
	ESO225 (8)	MSE202(11)	MSE302 (9)	MSE 306 (9)	OE-1 (9)	OE-4 (9)
	MSE201 (11)	MSE203 (11)	MSE303 (9)	DE-1 (9)	OE-2 (9)	OE-5 (9)
	MSE204 (9)	MSE205 (8)	MSE304 (9)	DE-2 (9)	OE-3 (6-9)	OE-6 (9)
			MSE305 (9)		DEH-1 (9)	DEH-3 (9)
					DEH-2 (9)	
	TA211 (3)		MSE351 (3)	MSE353 (3)		
	TA212 (3)	MSE251 (3)	MSE352 (3)	MSE360 (6)		
Credits	54-56	56-58	51	51-56	60-63	54

- A student has to earn Minimum CPI of 8.0 for being eligible for B. Tech.-Honours
- Course taken under DEH-1/2/3 must be taken from those DEs which are 600 level or above
- *UGP-2 (MSE496) (9 credits) and UGP-3 (MSE497) (9 credits) are mandatory for BTH program
- UGP-1 (MSE396) (4 credits) and UGP-4 (MSE498) are optional (over and above the minimum credit requirements)
- +ESO Basket: ESO207/ MSO201/ HSO201/ MSO203M (One course required)

3. Bachelor of Technology and Management (BTM)

Courses for Semester-1 and 2 are same as in the template for B.Tech. (Template at entry No. 1)

	semester					
	3rd	4th	5th	6th	7th	8th
Courses	SCHEME-2 (9-11)	SCHEME-3 HSS-1 (9-11)		SCHEME HSS-II (9)	SCHEME HSS-II (9)	SCHEME HSS-II (9)
	ESO202 (11)	ESC201 (14)	MSE301 (9)	ESO Basket (6-11)+	MTB-1 (9)	OE-3 (9)
	ESO225 (8)	MSE202(11)	MSE302 (9)	MSE 306 (9)	MTB-2 (9)	MTB-4 (9)
	MSE201 (11)	MSE203 (11)	MSE303 (9)	DE-1 (9)	MTB-3 (9)	MTB-5 (9)
	MSE204 (9)	MSE205 (8)	MSE304 (9)	OE-1 (6-9)	OE-2 (9)	MTB-6 (9)
			MSE305 (9)			
	TA211 (3)		MSE351 (3)	MSE353 (3)		
	TA212 (3)	MSE251 (3)	MSE352 (3)	MSE360 (6)		
Credits	54-56	56-58	51	48-56	45	45

- MTB-1 to MTB-6 are courses from *Management track basket* worth 54 credits
- UGP-1 (MSE396) (4 credits) and UGP-4 (MSE498) are optional (over and above the minimum credit requirements)
- UGP-2 (MSE496) (9 credits) can be taken in lieu of one DE course
- UGP-3 (MSE497) (9 credits) can be taken in lieu of one OE course
- +ESO Basket: ESO207/ MSO201/ HSO201/ MSO203M (One course required)

4. *Double Major* program (For a student from another department who is seeking second major from the MSE Department)

(as per the BT template)

Odd Semester	Even Semester
Pre-Requisite	
ESO225 (8)	
TA211 (3); TA212 (3)	
Department Core Requirements	
MSE201 (11)	MSE202 (11)
MSE204 (9)	MSE203 (11)
MSE301 (9)	MSE205 (8)
MSE302 (9)	MSE306 (9)
MSE303 (9)	
MSE304 (9)	
MSE305 (9)	
Laboratory Courses	
MSE351 (3)	MSE251 (3)
MSE352 (3)	MSE353 (3)
	MSE360 (6)
Total credits 71	Total credits 51

- Total Mandatory credits for second major: 122
- Pre-Requisites: ESO225 (8 credits); TA211 and TA212 (3+3 credits) [a student should have done these courses prior to seeking entry into double major]

5. Dual Degree (B.Tech. + M.Tech.) template

➢ Category-A: for a student from the MSE department

Template for semester 1st to 6th remains same as that for B.Tech. (Template at entry No. 1)

	Semester				
Courses	7th	8th	Summer	9th	10th
	OE PG-1 (9)	OE PG-3 (9)	MTech Thesis/ DE PG-1/2 (18) (optional)	MTech Thesis (36)	MTech Thesis (36)
	OE PG-2 (9)	OE PG-4 (9)		MSE801 (0)	
	DE PG-1 (9)*	DE PG-2 (9)*			
Credits	27	27	18	36	36

- *Students from within Department can use up to 2 DE UG courses for PG part, that is, they can get up to 18 credits of waiver in their PG part in lieu of 2 DE courses taken in their UG part.

➢ Category-B: for a student from the department other than MSE

Template for semester 1st to 6th remains same as that for B.Tech. (Template at entry No. 1)

	semester				
Courses	7th	8th	Summer	9th	10th
	OE PG-1 (9)	OE PG-3 (9)	MTech Thesis (18)	MTech Thesis (27)	MTech Thesis (27)
	OE PE-2 (9)	OE PG-4 (9)		PG-1 (09)	PG-2 (09)
				MSE801 (0)	
Credits	18	18	18	36	36

6. Minor

Can be given in any of the three streams if a student completes 18 or more credits in a particular stream (Stream names to be revised later, and courses in individual streams would be revise and communicated later)

- Devices and Bio-Engineering Stream
- Structure-Characterization Stream
- Metals Processing Stream

DEPARTMENT OF MSE			
Courses ID	**Course Title**	**Credits L-T-P-D-[C]**	**Content**
MSE201	THERMODYNAMICS & PHASE EQUILIBRIA	3-1-0-0-11	This course will start with an introduction to basic terminology in Thermodynamics including the concepts of heat and work and explaining the need of state functions in defining the state of a system. Three laws of thermodynamics will be studied and their use in studying equilibrium processes will be illustrated by solving some example problems. The concept of entropy will be taught through the perspectives of both the classical thermodynamics and the statistical mechanics. State functions including enthalpy, Helmholtz free energy and Gibbs free energy will be derived and their application in defining state of equilibrium with selected sets of independent variables will be covered. The concept of heat capacity and its relation with temperature will be introduced. Application of heat capacity at constant pressure or constant volume in determining various state properties of a system will be illustrated. Once the basic framework of thermodynamics is established in the form of three laws of thermodynamics and the criteria for equilibrium, it will be then utilized to study phase equilibrium and stability, first in single component systems and then in binary solutions. Raoult's law, Henry's law, saturated vapor pressure and the concept of thermodynamic activity, Gibbs-Duhem equation and its application are some of the important concepts, which will be covered as a part of solution thermodynamics. Ideal solution and regular solution models will be explained in detail and extension to non-ideal systems will be introduced. Phase rule and its application in reacting as well as non-reacting systems will be studied. This will be followed by study of Gibbs free energy-composition diagrams and their applications in deriving various phase diagrams. Calculation of phase diagrams using CALPHAD approach will be introduced along with examples of a few binary phase diagrams using CALPHAD. Reaction equilibria in homogeneous gas mixtures as well as systems composed of gas and condensed phases will be covered. Students will be introduced to Ellingham diagrams for graphical determination of phase stability in oxide systems. Relation between chemical and electrical driving forces will be established based on the Nernst equation and application of various electrochemical cells in determining thermodynamic properties will be introduced. **Course Reference:** I. Thermodynamics of Solids: Richard A. Swalin; 2. Introduction to Thermodynamics of Materials: David R. Gaskell; 3. Physical Chemistry of Metals: L. Darken and R.W. Gury; 4. Problems in Metallurgical Thermodynamics and Kinetics: G. S. Upadhyaya and R. K. Dube; 5. Phase Equilibria in Materials: S.P. Gupta; 6. An Introduction to Thermodynamics: Y. V. C. Rao.

MSE202	RATE PROCESSES	3-1-0-0-11	1 Introduction to Fluid flow; 2. Introduction to heat transfer; 3. Introduction to mass transfer; 4. Mass transfer with Chemical reaction; 5. Introduction to Heterogeneous Reaction Kinetics; 6. Simultaneous Heat and Mass Transfer with Chemical reactions; 7. Introduction to Electrochemical Kinetics Course Reference: 1. Engineering in Process Metallurgy: R. Guthrie, Oxford Scientific Publications; 2. Transport Phenomena in Metallurgy: GH Geiger and DR Poirier; TMS publication; 3. Kinetic and metallurgical processes: Fathi Habashi; 4. Mass transport in solids and fluids: DS Wilkinson, Cambridge solid state science series.
MSE203	STRUCTURE & CHARACTERIZATION OF MATERIALS	3-1-0-0-11	Structure and Characterization of Materials is a UG compulsory curse for the students of Materials Science and Engineering which aims to lay down a strong foundation for the structure of different classes of materials like meals and alloys, polymers and ceramics for engineering applications. After covering one of the corners of the materials science tetrahedron of structure-processing-property-performance paradigm that is the bedrock of the discipline, the course moves to cover characterization of materials which is at the centre of the tetrahedron and is the fulcrum on which the science of materials rests in balance. This will be achieved by covering diffraction techniques like x-ray and electron diffraction; imaging using visible light and electrons and different spectroscopic techniques like energy and wavelength dispersive spectroscopy in greater depth. It is expected that the students should appreciate the complexity and inherent hierarchy of the structure and microstructure of engineering materials and ways to decipher the same by the md of this course. Course Reference: 1. The structure of materials, S.M. Allen and E. L. Thomas, John Wiley and Sons, 1998; 2. Microstructural Characterization of Materials – D. Brandon and W.D. Kaplan, John Wiley and Sons, 2008; 3. Electron Microscopy and Analysis, Peter J. Goodhew, John Humphreys and Richard Beanland; 4. Elements of X-ray diffraction, B.D. Cullity and S.R. Stocks, Addison-Wesley Publishing Co.; 5. Introduction to solids, L.V. Azaroff, McGraw-Hill Book Company; 6. Elementary Crystallography by M.J. Buerger; 7. Crystals and Crystal structures, R.J.D. Tilley, John Wiley and Sons, 2006; 8. Fundamentals of Materials Science-the microstructure-property relationship using metals as model systems, E.J. Mittemeijer, Springer, 2010; 9. Scanning Electron Microscopy and X-Ray Microanalysis, J. I. Goldstein et al.,Third edition, Springer, 2003
MSE204	COMPUTATIONAL METHODS IN MATERIALS SCIENCE AND ENGINEERING	3-0-0-0-9	Introduction to Python. Solution of linear and non-linear equations. Numerical methods for solving initial and boundary value problems, with examples from some of the most famous differential equations like Newton's second law of motion, Schrodinger equation, Laplace, Poisson, diffusion, heat transport and wave equations. Data analysis and visualization, binomial, Poisson and normal distribution, different

			type of regression (linear, non-linear, logistic). Fourier transform. Hands-on training will be provided along with lectures. Course Reference: 1. Advanced Engineering Mathematics, Erwin Kreyszig; 2. Differential Equations with Boundary Value Problems, Dennis G. Zill. 3. Computational Physics, Mark Newman. 4. Mathematics for Machine Learning, Marc Peter Deisenroth.
MSE205	PHYSICS OF MATERIALS	2-1-0-0-8	Drude's model and Sommerfeld's model of electrical conduction, Fermi-Dirac distribution, Reciprocal lattice and Brillouin zone, Bloch Theorem, Kronig-Penney model, Origin of energy bands and band-gap, $\mathcal{E}$-k diagram, electron dynamics, Band structure of metals, semiconductors, and insulators; Concept of phonons, phonon interactions and scattering, Specific heat, thermal conductivity; Optical spectra of atoms and molecules, Franck-Condon principle, selectivity of optical transitions, excitons. **Course References:** 1. Electronic Properties of Materials: An Introduction for Engineers, Rolf E. Hummel, Springer Verlag,1985; 2. Solid State Physics, Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia, USA, 1976; 3. Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons 1991; 4. Optical Processes in Solids , Y. Toyozawa , Cambridge University Press , 2003; 5. Principles of the Theory of Solids , J. M. Ziman , Cambridge University Press , 1979; 6. Solid State Physics for Engineering and Materials Science, John P. McKELVEY , Krieger Publishing Company, 1993; 7. Optical Processes in Solids , Y. Toyozawa , Cambridge University Press , 2003.
MSE251	PHYSICAL METALLURGY AND MATERIALS CHARACTERIZATION LABORATORY	0-0-3-0-3	There are 12 basic experiments which will introduce the student to the use of different equipment in a standard physical metallurgy and materials characterization laboratories. **Course references:** 1. Principles of Metallographic Laboratory Practice by G.L. Kehl; 2. Physical Metallurgy by V. Raghvan; 3. Engineering Physical Metallurgy by Yu. Lakhtin; 4. Material Science by S P Gupta; 5. Microstructural Characterization of Materials – D. Brandon and W.D. Kaplan, John Wiley and Sons, 2008; 6. Materials Characterization Techniques, S. Zhang, Lin Li and Ashok Kumar, CRC Press, 2009
MSE301	PHASE TRANSFORMATIONS	3-0-0-0-9	This course will begin with a broad classification of phase transformations followed by a few important concepts related to phase transformations, e.g. Gibbs free energy change calculations, interfaces and diffusion in solids. This course will further discuss several topics related to solid state phase transformations, e.g., nucleation, growth, coarsening, overall transformation kinetics, precipitation and spinodal decomposition, recrystallization and grain growth, martensitic transformation and isothermal and continuous cooling transformation. This course will also briefly describe few important concepts related to solidification.

			Course References: 1. Phase Transformations in Metals and Alloys, David A. Porter, Kenneth E. Easterling, Mohamed Sherif, CRC Press, Taylor and Francis Group; 2. Phase Transformations in Materials by R. C. Sharma, CBS Publishers, New Delhi; 3. Solid State Transformations by V. Raghavan, Prentice-Hall of India, New Delhi; 4. Mechanisms of Diffusional Phase Transformations in Metals and Alloys Hubert I. Aaronson, Masato Enomoto, Jong K. Lee, CRC Press; 5. Physical Metallurgy Principles, R. E. Reed-Hill; 6. Transformation in Metals, P.G. Shewmon; 7. Phase Transformations in Materials, A. K. Jena
MSE302	MECHANICAL BEHAVIOUR OF MATERIALS	3-0-0-0-9	Elasticity, Plasticity, Dislocations, Strengthening mechanisms, Fracture, Fatigue, Creep, Deformation behaviour of materials with ordered structure non-metallic materials. **Course References:** 1. Mechanical Behaviour of Materials, M.A. Meyers and K.K. Chawla; 2. Introduction to Dislocations, Hull and Bacon; 3. Mechanical Metallurgy, G.E. Dieter; 4. Mechanical Behaviour of Materials, Courtney; 5. Theory of Elasticity, Timoshenko; 6. An Introduction to Mechanics of Solids, S.H. Crandall and N.C. Dahl; 7. Deformation and Fracture Mechanics, R.W. Hertzberg; 8. Mechanical Testing, Metals Handbook; 9. Recrystallization and Related Annealing Phenomena, F.J. Humphreys.
MSE303	ELECTRONIC & MAGNETIC PROPERTIES OF MATERIALS	3-0-0-0-9	Intrinsic and extrinsic-semiconductor, n- and p-type semiconductors; Fermi level, Carrier concentration and mobility, Dielectric constants and polarization, Non-linear dielectrics (Pyro/Piezo/Ferro-electric materials), Ionic conductors, Defect chemistry using Kröger-Vink notation, Impedance spectroscopy, Nyquist Plot, Mixed ionic electronic conductor, Magnetism (diamagnetism, paramagnetism, and Pauli-paramagnetism, Ferro-, antiferro- and ferri- magnetism, ferrites), Superconductivity, Light interaction with materials (refraction, reflection, absorption and transmission; refractive index, Fresnel Equation, Snell's Law Course Reference: 1. Electronic Properties of Materials: An Introduction for Engineers, Rolf E. Hummel, Springer Verlag, 1985; 2. Solid State Physics, Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia, USA, 1976; 3. Introduction to Solid State Physics, Charles Kittel, John Wiley & Sons 1991; 4. A.J. Moulson & J. M. Herbert, "Electroceramics: Materials, Properties, Applications", Publisher : Wiley; 5. Jaffe B., Cook W. R. and Jaffe H., "Piezoelectric Ceramics," Academic Press, New York, (1971); 6. Principles and applications of ferroelectrics and related materials, M. Lines & A. Glass, Oxford University Press, New York; 7. "Impedance Spectroscopy: Theory, Experiment and Applications", Edited by J. Ross Macdonald & Evgenij Barsoukov, Publisher: John Wiley and Sons; 8. M. W. Barsoum, "Fundamentals of Ceramics", Publisher: Institute of Physics; 9. D. M. Smyth, "The Defect Chemistry of Metal Oxides", Publisher: Oxford University Press; 10. Principles of Electronic

			Materials and Devices, S. O. Kasap, McGraw Hill Education (India) Private Limited 2020
MSE304	PRINCIPLES OF METAL EXTRACTION & REFINING	3-0-0-0-9	Process mass and heat balance, Thermodynamics and Kinetics in metals extraction and refining, principles of mineral beneficiation, principles of pyro-metallurgy, principles of electrometallurgy, principles of hydrometallurgy, general issues related to metal extraction, refining of metals. Course Reference: 1. H S Ray and A Ghosh: Principles of Extractive Metallurgy, 3rd Edition, New Age International Publishers, 2018; 2. Terkel Rosenqvist: Principles of Extractive Metallurgy, 2nd Edition, Tapiar Academic Press, 2004; 3. Barry Willis: Mineral Processing Technology, 8th Edition, Elsevier, 2015; 4. T A Engh: Principles of metal refining, Oxford Scientific Publications;1992
MSE305	MATERIALS PROCESSING	2-0-0-0-6	Materials Processing course will focus on the material processing aspects including solidification processing, mechanical working, material and ceramic powder processing, joining, and thin-film coating. Solidification aspects in casting will be emphasized with various processing techniques and continuous casting. Mechanical working will focus on workability of materials with rolling, forging, extrusion, sheet metal forming, machining and defects. Section on powder processing of metals and ceramics will focus on compaction, microstructure, pore size, and stages of sintering with select case studies. Joining processes will include welding, brazing, soldering and adhesive joining. Various fusion welding techniques, resistance welding, solid-state welding and thermit welding techniques will be discussed. Thin film coating techniques will hover on vacuum, types of vacuum pumps, physical vapor deposition, chemical vapor deposition and thermal spray coating techniques Course Reference: 1. R.W. Heine, C.R. Loper, and P.C. Rosenthal, Principles of Metal Casting, 2nd ed., 1967; 2. A. Upadhyaya, G.S. Upadhyaya: Powder Metallurgy Science, Technology and Materials (2011); 3. Donald Leonard Smith; Thin film deposition: principles and practice; McGraw Hill; 4. J.N. Harris, Mechanical Working of Metals Theory & Practice, Pergamon Press, Exeter, UK, 1983; 5. H.H. Gatzen, V. Saile, J. Leuthold, Micro and Nano Fabrication, Springer Berlin Heidelberg (2015); 6. P.L. Fauchais, J.V.R. Heberlein, M.I. Boulos, Thermal Spraying Fundamentals, Springer New York (2014); 7. M. P. Groover, Fundamentals of Modern Manufacturing: Materials, Processes and Systems, John Wiley & Sons Inc., 2007
MSE306	IRON & STEEL MAKING	3-0-0-0-9	Ironmaking: Blast furnace ironmaking, Principles of heat and material balance, Modern developments in blast furnace operations, Sponge ironmaking, Pretreatment of hot metal, Steelmaking: Principles of steelmaking, Oxygen steelmaking processes, Electric furnace steelmaking, Ladle and tundish metallurgy, Casting processes, Refractories in iron and steelmaking, and Iron and steelmaking in India

			Course References: 1. A first course in Iron and Steelmaking: by D. Mazumdar, University Press, Hyderabad, 2015; 2. Ironmaking and steelmaking: Principles and Practices: A. Ghosh and Amit Chatterjee, Prentice Hall of India.
MSE351	MECHANICAL & ELECTRONIC MATERIALS LABORATORY	0-0-3-0-3	There are 12 basic experiments which will introduce the student to the use of different equipment in the measurement of mechanical and electronic properties of materials. References: 1. Mechanical Behaviour of Materials by Thomas H. Courtney; 2. Dislocations and Mechanical Behaviour of Materials by M. N. Shetty; 3. Introduction to Dislocations by D. Hull and D. J. Bacon
MSE352	PROCESS METALLURGY & MANUFACTURING LABORATORY	0-0-3-0-3	There are 12 basic experiments which will introduce the student to processing of materials, manufacturing of materials and extractive metallurgy of metals. Reference: Principles of metallographic laboratory practice by G. L. Kehl
MSE353	INSTRUMENTATION FOR MATERIALS ENGINEERING LABORATORY	0-0-3-0-3	8 laboratory experiments to introduce students to the idea of instrumentation which can be applied for developing equipment for measuring material characteristics and properties. 4 laboratory sessions would be used for project where students would utilize their imagination and creativity to develop a simple instrument. **Course references:** 1. Analogue and Digital Electronics for Engineers: An Introduction, by Ahmed and Spreadbury (Cambridge University Press); 2. Arduino Programming: The ultimate guide for making the best of your Arduino programming projects, by Damon Parker; 3. Raspberry Pi Cookbook by Simon Monk (O'Reilly)
MSE360	CAPSTONE PROJECT LABORATORY	0-0-6-0-6	This project will be culmination of ideas and concepts picked up in the core courses and laboratories. Relevant departmental labs will be reserved for 6 hrs during the week for the students to work on their projects. In this way the students can do a comprehensive design/ fabrication/ exploration project using the knowledge derived from all of the labs (including instrumentation). The project (which could be a construction of an instrument or could exhibit an important principle) should have one or more of the following elements: a. Device design and fabrication, b. Correlating processing with structure, property and performance, c. Instrument design and development
ESO225	Nature and Properties of Materials	2-1-0-0-8	The course will describe the basics of materials science: bonding, structure, properties, performance, material use and recycle. The properties and performance of any material system is directly related to bonding, crystal structure and microstructure. Correlation of the properties and performance from the prospective of structure of materials will be discussed. Materials, which have enabled progress over thousands of years, are now facing severe limits set by sustainability. The course will have tutorial and lab component. In the tutorial the design of materials using computational tools will be taught. In the lab component of the course, the students will be

			engaged with interesting and focussed experiments related concepts and topics discussed in the course lecture component.
TA211	MANUFACTURING PROCESSES I	0-0-3-0-3	Demonstration and practice of green sand molding, sheet metal forming, welding & brazing process, and single-point tool operations. In addition, few demonstrations on powder metallurgy, rolling/swaging, and multi-point tool operations and structural/hardness will also be provided. Main aspect of the lab course is developing a project that must involve conceptualization of idea, expressing it via engineering drawing, and realizing it via incorporation of learnt manufacturing techniques in fabricating the parts/component/structure and assembling/joining the same.
MSE396	UNDER GRADUATE PROJECT I	4 credits	UG PROJECT (UGP-I)
MSE496	UNDER GRADUATE PROJECT II	9 credits	UP PROJECT (UGP-II)
MSE497	UNDER GRADUATE PROJECT III	9 credits	UG PROJECT (UGP-III)
MSE498	UNDER GRADUATE PROJECT IV	9 credits	UG PROJECT (UGP-IV)
MSE422	SELECTION AND DESIGN OF ENGINEERING MATERIALS	3-0-0-0-9	Overview of the design process: concepts and stages of engineering design and design alternatives to develop materials with tailored properties; Performance indices of materials; function, objective and constraints in design, specific stiffness limited and strength limited design for maximum performance, Performance indices for thermal, mechanical, thermomechanical applications, damage tolerant designs for structural applications; Basic concepts of materials science: processing structure property performance correlation; overview of conventional and advanced materials; Brief overview of the elements of chemical bonding, crystal structure, defect structure of different material classes, Brief introduction to the manufacturing processes for metals, polymers, ceramics, glasses and composite materials; design for manufacturability, Ashby's material property charts; Decision matrices and decision matrix techniques in materials selection, relationship between materials selection and processing; Case studies: designing of Metals and alloys, ceramics and glasses, composite materials (MMC,CMC and PMC/ FRC) for specific applications.
MSE425	PROCESS PLANT DESIGN FOR METT. ENGG. OPERATIONS	3-0-0-0-9	Identification of process flow sheet: Preliminary estimate of resources and facilities: Materials and energy balance, detailed plant flow sheet: Equipment selection and specification, economic selection and specification: environmental impact analysis: Report presentation, case studies of typical metallurgical plant operation.
MSE467	MATERIALS FOR SEMICONDUCTOR INDUSTRY	3-0-0-0-9	Semiconductor fundamentals, band structure, indirect and direct band gap, optical properties, carrier statistics, semiconductor material purification and crystal growth, epitaxy, CVD and MBE, PN Junction, Schottky and MOS device structures, specific material requirements,

			Doping by implantation and diffusion, dielectric and insulators, ohmic and barrier contacts, band edge behaviour, empirical rule, alloy design.
MSE470	MANUFACTURING PROCESS	3-0-0-0-9	It will discuss various established as well as upcoming manufacturing processes.
MSE480	MATERIALS DEGRADATION & ITS PREVENTION	2-0-0-0-6	Types of processes leading to degradation of materials, viz Oxidation Corrosion,Wear, Creep and fatigue review of basics of thermodynamics and kinetics related to oxidation and corrosion studies, Pourbaix diagram, Polarization, Mixed potential theory, Passivity Characteristics of passivation ; Various types of degradation: atmospheric galvanic, intergranular, dealloying, crevice and pitting corrosion, microbiological, stress corrosion cracking, hydrogen damage, radiation damage; Oxidation and hot corrosion of materials at high temperatures; Wear of materials, analytical models of wear; Prevention of material degradation alloying, environment conditioning design modification cathodic and anodic protection, metallic coating inorganic coating organic coating, inhibitors and passivators wear resistant materials structural modifications, wear resistant coatings.
PG LEVEL COURSES			
MSE601	DISPLAY MATERIALS & TECHNOLOGIES	3-0-0-0-9	Overview of display industry, information capacity of displays, introduction to different flat panel display technologies, applications and comparison; Fundamentals of Photometry, including luminance and brightness; Colorimetry: visual basis of colorimetry, psychophysical experiments to quantify colour, CIE colorimetry; Characterization and performance of displays: Concepts of aspect ratio, colour gamut, contrast and gradation, directional visibility, driving power, efficiency, speed, memory and storage, degradation, resolution, addressability, physiological factors, and measurement instrumentation; Luminescence and luminescent materials: Physical processes and interactions leading to emission of light, processes responsible for the transfer of energy in luminescent materials, chemistry and preparation of luminescent materials, and emission properties of the prepared materials; Basics of matrix addressing of displays: active and passive matrix; Technical discussion of display technologies: (a) Light Emitting Diodes (LEDs): Introduction to p-n junction, hetero-junctions, recombination processes, semiconductor materials (III-V, II-VI, SiC, ternary and quaternary alloys) for LEDs and device structures; (b) Organic Light Emitting Diodes (OLEDs): development of multilayer device structure, doping, phosphorescent OLEDs, PIN type OLEDs, OLEDs to displays; (c) Liquid Crystal Displays (LCDs): Introduction to liquid crystals, physics of propagation of light in anisotropic media, different types of LCDs, and manufacturing technology, including cells assembly and colour filters; Other displays and associated technologies: cathode ray tube, plasma display panel, field emission displays, electroluminescent displays and E-paper technologies.

MSE603	NONEQUILIBRIUM PROCESSING OF MATERIALS	3-0-0-0-9	Introduction to nonequilibrium processing Thermodynamics and kinetics of metastable phase formation; Rapid solidification: Undercooling. Phase diagram metastable states, Methods of rapid solidification, Microstructure formation by rapid solidification, Application for rapid solidification ; Mechanical alloying: Process of mechanical alloying, Mechanism of alloying Energy criteria for mechanical alloying, Synthesis of nonequilibrium phases, Application of mechanical alloying, Metallic glass : Understanding of glass formation, thermal stability and glass forming ability, structure of metallic glass, crystallization behavior, properties of metallic glass, application, Special nonequilibrium processing and phase transformations
MSE604	SCIENCE AND TECHNOLOGY OF THIN FILMS AND DEVICE FABRICATION	3-0-0-0-9	1. Introduction behaviour to device processing steps, examples of various devices (with emphasis on solar cells and MOSFETs) Need for miniaturization Thin Film Deposition; 2. Basics of thin film: Brief review of kinetic theory for growth. Adsorption and desorption; 3. Film growth: nucleation and growth kinetics Epitaxy Thin film growth control. PVD Processes Evaporation (Thermal and e-beam), Principles of glow discharge and various sputtering processes; 4. Chemical Growth Fundamentals of CVD growth Processes of Modern variants: MOCVD, PECVD and ALD Spin Coating; 5. Basic Thin Film Thickness measurement. Characterization Phase analysis, Optical analysis Morphology analysis, Device Fabrication; 6. Substrate seiection: Selection of substrates and preparation, Single crystal growth (Silicon). Role of substrate surface and contaminants Physical and chemical methods of substrate surface preparation; 7. Pattern fabrication Concepts of lithography Photoresists (Negative, Positive etc) Exposure Development of Masking Variants of lithography with emphasis on Photo and e-beam Precautionary steps; 8. Material Removal Wet (Chemical) and dry (Plasma, RIE etc.) etching; 9. Jon implantation, Doping and ion Implantation Doping, oxidation and Diffusion control of composition in devices and heat treatment Oxidation and heat treatment 10. Metallization and Adhesion and morphology issues Interconnects Introduction to electromigration vis-a-vis metallization: Impact on device performance and methods of prevention. Process Integration: Example of process integration for a particular kind of devices e.g., Si Solar Cell, MOSFET. **Course references:** 1. VLSI Fabrication: S.K. Gandhi Si Processing (Volume I and II) Lou and Mayer; 2. Introduction to Microfabrication by Sami Fransilla (Wiley); 3. Fundamentals of Microfabrication: The Science of Miniaturization by Marc Madou (CRC Press); 4. Thin film deposition by Donald Smith (Me Graw Hill) Materials science of thin films by Milton Ohring (Academic Press); 5. Pulsed Laser deposition of thin films by Chrisey and Hubler (Wiley Interscience)

MSE605	SURFACE PHENOMENA AND CHARACTERIZATION	3-0-0-0-9	Surface Chemistry/Interaction (surface charge, dipoles, energies, interfacial chemical reactions), Surface Phonons/Plasmons (Quantisation of plasma, light and, sound, Brillouin Zones), Elastic/Inelastic scattering, Electromagnetic scattering (Compton, Rayleigh, Rutherford, Thomson), Crystal structure and Reciprocal Lattice, Brillouin Zone, Surface Diffusion (Fick's law, intergranular/amorphous layer formation),Surface Energy/Young's Equation (Capillary/surface tension in fluids), Surface Sensitive Properties: Passivation/Adsorption (Forces/Chemical bonds on surface), Interfacial wetting (formation of interfaces, contact angle in wetting surfaces), Density functional theory of atomic equilibrium, Case Studies: FeB49 system, and Al2O3 carbon nanotube, Surface Modification/Functionalization Nanostructures: Self Assembly (adding molecules to surface), Distribution of phase : Voronoi and Dirichlet Tessellation, Molecular Sieves (Molecular filters : purification of gases/chemicals etc). **Course Reference:** 1. Materials Science and Tedmology. Ed. R.W. Kahn, P. Hassen, E.J. Kramer, Vol. 2n/2b, Wiley YCII (2005); 2. Physics of Atoms and Molecules. B.H. Bransden, and C.J. Joachain, Longman (1996); 3. Surface Analysis Methods in Materials Science, D. J; Connors, B.A. Sexlon, and R. St. C. Smart, Springer (2003); 4. The Physics and Chemistry of Materials, J. I. (Gersten, F. W. Smith. Wiley (2001); 5. Elementary-Solid State Physics. M. A, Omar, AddisonWesley (2001).
MSE607	COMPUTING APPLICATIONS IN METALLURGY	3-1-0-0-11	Fortran fundamentals: Applications of regression analysis and curve fitting techniques, computer calculations of phase diagrams: Numerical of partial differential equations pertinent to heat, mass and momentum transfer: Computer applications in solidification, potential energy diagrams and experiment in metallurgy.
MSE608	MICROSTRUCTURE MODELLING AND SIMULATION	3-0-0-0-9	Importance of microstructure modelling and simulation, brief description of analytical and numerical approaches for studying microstructure evolution at different length scales, numerical solution of differential equations, finite difference, discretization, boundary conditions, stability conditions, structure of a code, input parameters and visualization, numerical solution of simple 1D and 2D diffusion problems. Cellular Automata: Introduction and basic description of Cellular Automata (CA), probabilistic and lattice gas CA, applications of CA in materials science and engineering, 1D and 2D CA models for recrystallization, 2D CA model for grain growth. Monte Carlo Potts Model: Fundamentals of Potts model, Two state Potts model, Q-state Potts model, efficient algorithms, application of Potts model: Zener pinning, abnormal grain growth etc. Phase-Field Method: Brief history of development of phase-field method (PFM), representation of a microstructure using phase-fields, thermodynamics – concepts of free energy, kinetics – evolution equations, effect of external fields on microstructure evolution. Several case studies on microstructure modelling using PFM, e.g. precipitate

			growth and coarsening, spinodal decomposition, eutectic and dendritic solidification, eutectoid transformation, grain growth etc. Multiscale Modelling and Integrated Computational Materials Science Approach (ICME): Basic concepts and examples. **Course References:** 1. Computational Materials Engineering, An Introduction to Microstructure Evolution, K.G.F. Janssens, D. Raabe, E. Kozeschnik, M. A. Miodownik, B. Nestler (Academic Press); 2. Introduction to Computational Materials Science Fundamentals to Applications, Richard LeSar (Cambridge University Press); 3. Continuum Scale Simulation of Engineering Materials: Fundamentals - Microstructures – Process Applications, Edited by Dierk Raabe, Franz Roters, Frédéric Barlat, Long-Qing Chen (Willy-VCH Verlag GmbH & Co.KGaA); 4. Mathematics of Microstructure Evolution, Edited by L.-Q. Chen, Brent Fultz, John W. Cahn, John R. Manning, John E. Mortal, John Simmons (TMS, siam); 5. Computational Materials Science: The Simulation of Materials, Microstructures and Properties, Dierk Raabe (Wiley-VCH Verlag GmbH); 6. Phase-Field Methods in Materials Science and Engineering, Nikolas Provatas and Ken Elder (Willy-VCH Verlag GmbH & Co.KGaA)
MSE611	CORROSION AND OXIDATION OF METALS AND ALLOYS	3-0-0-0-9	Introduction to Corrosion and Oxidation; Review of basics of Thermodynamics and Kinetics related to corrosion and oxidation; Pourbaix diagram and its relation to aqueous corrosion; Basic electrochemistry related to corrosion and advanced theory of electrochemical kinetics and corrosion; Polarization; Mixed potential theory; Passivity; Various types of corrosion: Galvanic, Intergranular, Crevice, Pitting, Dealloying, Erosion corrosion, Stress corrosion and hydrogen embrittlement; Corrosion protection mechanism and methods; Oxidation and hot corrosion at high temperatures; Interaction between metals and different gases and Ellingham diagram; Wagner laws of oxidation; Oxide structure and oxidation; Oxidation protection mechanisms and methods; Coatings: Different types of Coatings, Coating methods and characteristics of Coating. **Course References:** 1. Corrosion: L.L. Shreir, NewnesButterworths (London), 1976; 2. Corrosion and Corrosion Control: HH Uhlig and W. Revie, Wiley, New York, 2007; 3. Corrosion Science and Technology. David Talbot, James Talbot, CRC Press, 1998; 4. Corrosion Engineering by Mars. G. Fontana, Third ed. TMH; 5. Environmental Degradation of Metals: UK Chatterjee, S K Bose and S K Roy, MarcelDekker, 2001; 6. Oxidation of Metals and Alloys: 0. Kubaschewski and B.E. Hopkins, Butterworths (London) 1967; 7. High Temperature Oxidation of Metals: P. Kofstad, John Wiley & Sons, Inc, 1966; 8. Materials Degradation and Its Control by Surface Engineering: A. W. Batchelor, L. N. Lam and M. Chandrasekharan, Imperial College Press, 2002
MSE613	ELECTROCHEMICAL TECHNOLOGY IN	3-0-0-0-9	Thermodynamic of electrolyte, electrochemical potential, conduction of ions in solution, overpotential, absorption, phase formation: Economics of an electrolytic process, principles of cell design,

	MATERIALS PROCESSING		Electrochemical technology: Electrowinning, electrorefining and metal electroforming, electrochemical machining, electroplating, anodizing, pickling, electrophoretic painting, electrochemical treatment of minerals, batteries and fuel cells, water treatment and environmental protection.
MSE615	STRUCTURE AND CHARACTERIZATION OF MATERIALS	3-0-0-0-9	Basic crystallography and crystal structures (8 Lectures hour) Periodic patterns, Lattices, Motif, Unit cells, Crystal structure, Primitive and Non primitive cells , Symmetry elements and point group notations, Crystal systems and Bravais lattices, Crystallographic directions and planes, Miller indices and Weiss zone law, Stereographic projections, Bonding in materials and atomic packing in metals, coordination number concepts, Covalent bonding, glasses and polymers, Crystal defects and their significance (12 Lectures hours) Point defects and their role in materials Processing, performance and failure , Ionically bonded structures: Pauling's rules and some examples, Point defects: thermodynamics, Schottky and Frenkel defect, Kröger-Vink notation, defect interactions, Dislocations, burgers vector, types of dislocations, Dislocation movement, slip systems, energetics of dislocations and their interactions 2, Planar defects: stacking faults, grain boundaries (low angle and high angle), antiphase **Course References:** 1. Crystals and Crystal structures, R.J.D. Tilley, John Wiley and Sons, 2006; 2. Materials Science and Engineering W.D. Callister, Jr. Wiley India(P) Ltd., 2007; 3. Materials Science and Engineering, G.S. Upadhyaya and Anish Upadhyaya, Viva books, 2010; 4. Fundamentals of Materials Science: The microstructure property relationship using metals as model systems, E.J. Mittemeijer, Springer, 2010; 5. Microstructural Characterization of Materials D. Brandon and W.D. Kaplan, John Wiley and Sons, 2008; 6. Science of Microscopy, P.W. Hawkes and J.C.H. Spence, Springer, 2007; 7. Scanning Electron Microscopy & XRay Microanalysis, J.Goldstein et.al, Springer, 2003; 8. Transmission Electron Microscopy B.D.Williams & C.B.Carter, Springer, 2009; 9. Surface Analysis methods in materials science, Editors: D.J.O;Connor, B.A. Sextton, R.St. C. Smart, Springer, 2003; 10. Materials Characterisation Techniques, S. Zhang, Lin Li and Ashok Kumar, CRC Press, 2009
MSE616	THERMODYNAMICS OF MATERIALS	3-0-0-0-9	1.Thermodynamic systems and variables: First, second and third laws of thermodynamics; Statistical interpretation of entropy; 2. Free energy functions and criteria for equilibrium; 3. Thermodynamics of solutions. Ideal and nonideal solutions, Partial and molar quantities; 4. Quasi chemical model and regular solutions; 5. Polynomial expressions for excess Gibbs energy of mixing for binary and higher order solutions. Multicomponent dilute solutions and interaction parameters. Chemical reaction equilibrium, equilibrium constant; applications to materials and metallurgical systems. Electrochemical systems, cell reactions and EMF, Formation and concentrations cells. Phase rule and binary phase

			diagrams to Free energy composition diagrams 3Phase equilibrium calculations 5Introduction to ternary phase diagrams.
MSE617	MATHEMATICS AND COMPUTATIONAL METHODS	3-0-0-0-9	1. Introduction of functions, vectors, matrices;2. Partial Differentiation (Total differentiation, Maximum and minimum: method of Lagrange multipliers, Change of variables: Legendre transformation, Differentiation of integral; Leibniz rule); 3. Multiple Integration (Change of variable: Jacobian, Surface and volume integrals); 4. Vectors (Geometry: Lines and planes, Directional derivative, gradients (fields, equipotential, grad, normal to surface, curl, div), Line integration (conservative fields, potential, exact differentiation), Green, Stokes, Div and Curl theorems; 5. Coordinate Transformation (Linear transform, Orthogonal transform, Eigenvalues: diagonalization of matrix); 6. Ordinary differential equations (Linear first order, Second order: constant coefficient and zero right hand side, Second order: constant coefficient and non-zero right hand side); 7. Statisticsa. Introduction to random experiment, computing probability of an event
MSE621	XPS AND AES IN STUDY OF SURFACE AND THIN FILMS	3-0-0-0-9	Solid surfaces, their structure and composition: Importance of the surfaces/ Surfaces in different materials/ Structural imaging/ Composition of surface selvedges; Practical detection and spatial limits; Chemical state information; Techniques to probe electronic structure at surfaces. Xray Photoelectron Spectroscopy Basics: Principles; Instrumentation; Vacuum systems, Xray sources, synchrotron radiation, electron energy analyzers; Spectral information, chemical shifts and interpretations; Quantification, depth profiling, imaging. XPS Applications: Catalysis; polymers and organic materials; corrosion, passivation and oxidation; superconductor; semiconductors; metallurgy/ tribology; thin films; Biomaterials, Case studies and lab visit/demo. Auger Electron Spectroscopy Basics: Principles; Instrumentation; Vacuum requirements, Electron sources, electron energy analyzers; Spectral information and interpretation; Quantification, depth profiling, imaging. **Course References:** 1. Surface and Thin Film Analysis, Editors; G. Friedbachaer and H. Bubert, WileyVCH, 2011; 2. Encyclopedia of Materials Characterisation, C.R. Brundle, C.A. Evans and S. Wilson, Butterworth Hennmann, 1992, Boston; 3. Introduction to Photoelectron spectroscopy P.K. Ghosh, John Wiley and Sons, WileyInter science, 1978, New York; 4. Surface Analysis Methods in Materials Science, D.J. ;Connors, B.A. Sexton, and R. St. C. Smart, Springer (2003); 5. Photoelectron and Auger spectroscopy. Thomas A Carlson, Plenum, New York, 1975; 6. Topics in Current physics: Electron spectroscopy for surface analysis, Ed. H. Ibach, Springer Verlag, Berlin, 1977; 7. Scanning Auger electron microscopy, Editors: M. PLrutton and Mohamed M. El Gomati, John Wiley & Sons, 2006; 8. Practical guide to surface science and spectroscopy. Yip Wah Chung, Academic Press, Boston, 2001.

MSE622	OPTICAL SPECTROSCOPY IN MATERIALS SCIENCE	3-0-0-0-9	Review of QM and light matter interaction. Electronic and vibrational energy states in materials. Point Groups, Symmetry and Selection Rules. Instrumentation – sources, spectrometers and detectors. Absorption spectroscopy: Mossbauer, UV/Vis-atomic absorption, IR-absorption (FTIR). Emissions Spectroscopy: Optical emission spectroscopy, UV/Vis-atomic emission, UV/Vis-Fluorescence and phosphorescence, and Photoluminescence. Reflections: spectrometery and Ellipsometery; Light scattering spectroscopy: Rayleigh and Raman Scattering (SERS, TERS, Resonance Raman and FT-Raman). Other spectroscopic techniques: Ultra-fast laser spectroscopy, photo-thermal and photo-acoustic spectroscopy, electron spectroscopic techniques. Case studies/ Applications: from metals, ceramics, semiconductors, organic molecules and polymers, bio-materials and nanomaterials. **Course references:** 1. Introduction to Spectroscopy by Donald L. Pavia , Gary M. Lampman, George S. Kriz and James R. Vyvyan (CENAGE Learning, 5th Ed.); 2. The basics of Spectroscopy by David W. Ball (PHI); 3. An Introduction to the Optical Spectroscopy of Inorganic Solids by J. Garía Solé, L.E. Bausá and D. Jaque (Wiley); 4. Symmetry and Spectroscopy by Daniel C. Harris and Michael D. Bertolucci (Dover Publications); 5. Molecular Structure and Spectroscopy by G. Aruldhas (PHI Learning); 6. Raman Scattering in Materials Science Edited by W.H. Weber and R. Merlin (Springer); 7. Infrared Spectroscopy: Fundamentals and Applications by Barbara Stuart (Wiley)
MSE624	ENERGY MATERIALS AND TECHNOLOGIES	3-0-0-0-9	Relevance of renewable energy generation, conservation and harvesting vis-à-vis environmental concerns (Energy requirement of society and depleting fossil fuels; Break-up of various renewable energy sources and consumption patterns). Solar cell device physics, LED device physics. Solar energy: amount of energy available area wise; Available solar energy technologies. PV technologies, materials, processes and issues. First generation technologies – Si based thin film (a-Si), CdTe, CIGS, Solar concentrators, Third generation (high efficiency and low cost) – Organic and dye solar cells, multi-junction, quantum dots. Present Status and future outlook and Indian Scenario. Solar energy: amount of energy available area wise; Available solar energy technologies. PV technologies, materials, processes and issues First generation technologies – Si based. Thin film (a-Si, CdTe, CIGS), Solar concentrators, Third generation (high efficiency and low cost) – Organic and dye solar cells, multi-junction, quantum dots. Present Status and future outlook and Indian Scenario. Description of Operation, Configurations, Cell Components, Materials Requirements, Manufacturing Techniques, Losses, Efficiency. Solid Oxide Fuel Cells, Solid Oxide Electrolyzer Cells, Batteries, Capacitors, Working principles

			and case studies of with emphasis on materials, their selection vis-à-vis their characteristics: Piezoelectric Sensors, Actuators, Transducers and MEMS. Thermoelectric, Applications: Ultrasound Imaging, Pyroelectric Sensors IR imaging. **Course references:** 1. Handbook of Photovoltaics Science and Technology, By Antonio Luque and Steven Hegedus; 2. Physics of Solar Cells, By Jenny Nelson 3. Physics of solar cells: from basic principles to advanced concepts, By Peter Würfel and Uli Würfel; 4. Organic photovoltaics: materials, device physics, and manufacturing technologies, By Christoph J. Brabec, Vladimir Dyakonov, Ullrich Scherf; 5. Principles of Solar Cells, LEDs and Diodes: The Role of the PN Junction, By Adrian Kitai; 6. Electroceramics: materials, properties, applications by A.J.Moulson and J.M. Herbert; 7. Electroceramics-based MEMS: fabrication-technology and applications, By Nava Setter
MSE626	TRANSPORT PHENOMENA	3-0-0-0-9	1. Fluid dynamics: Introduction to Transport phenomena in materials processing, Newton's law of viscosity, equation of continuity, Navier Stokes equations, Macroscopic mass and energy balance; Characteristics of industrial flows, Numerical problems on above topics of interest to metals and materials processing; 2. Heat transfer: Fundamentals of conduction heat transfer; Laws and equations; Steady and unsteady heat, conduction Numerical problems on conductive heat transfer, Fundamentals of convective heat transfer; free and forced convective heat transfer, Convective, heat transfer rate laws and heat transfer coefficient Problems on Convective heat transfer, Fundamentals of Radiation heat transfer and rate laws; view factors, Problems on Radiation heat transfer, Application of heat transfer in: Heat treatment, solidification, cooling of slabs, heat flow, through refractory walls etc; 3. Mass Transfer : Fundamentals of diffusion; rate laws, Uphill diffusion and Kirkendal's effect, steady and unsteady diffusion, Numerical problems on diffusion mass transfer, Fundamentals of convective mass transfer; free and forced convective mass transfer Kir Kendal's, Convective mass transfer, rate laws and mass transfer coefficient, Problems on Convective mass transport, Application of mass transfer in: case hardening, doping of semiconductors, homogenization, oxidation, absorption/desorption of gases in liquid metals. **Course Reference:** 1. Transport phenomena: D. R. Geiger and G. H. Poirier; 2. Transport phenomena: D. R. Gaskell; 3. Engineering in process metallurgy: R. Guthrie; 4. Mass transport in solids and fluids: D. S. Wilkinson. Other Recommended Reference books:1. Diffusion in solids: P. G. Shewrnan; 2. Atom movements diffusion and mass transport in solids: J. Philibert; 3. Diffusion in solids: field theory, solid-state principles, and applications: M. E. Glicksman

MSE627	CREEP AND HIGH TEMPERATURE DEFORMATION OF MATERIALS	3-0-0-0-9	Significance in engineering applications, Development of superalloys, Creep resistant alloys, Creep testing: Machines and Components, Creep at constant stress vs constant load, Creep under combined state of stress. Creep Phenomenology and Mechanisms Stages of creep: Primary, Secondary and Tertiary, Dependence of creep rate on stress and temperature, Creep analysis: Empirical, Phenomenological and Micromechanism based. Factors influencing creep, Temperature Compensated time, Zener-Hollomon parameter, Activation energy in creep, Temperature jump experiment. Role of diffusion, Diffusion pathways, Stress exponent, Stress jump test Independent and Sequential processes. Power law creep: Role of dislocations, Natural-three-power law, Five-power-law, Influence of the elastic modulus and stacking fault energy. Viscous theories of creep: Nabarro-Herring creep, Coble creep, Accommodation processes, Grain boundary sliding, Harper-Dorn Creep Microstructure factors affecting creep, Grain size effect, Inverse grain size exponent Substructural changes during creep, Subgrain formation and models, Influence of substructure on creep resistance, Pipe diffusion, Interface controlled diffusion creep Transient creep, Tertiary creep and Creep rupture: Cavity nucleation and growth. Creep and high temperature deformation of Advanced Alloys, Intermetallics and Ceramics. High temperature steels, Particle-strengthened alloys, Titanium alloys, Ni- and Co-base superalloys, Materials for aerospace and nuclear applications. Creep representation, Life Predication: Methods and Extrapolation models, Modelling of creep Deformation mechanism maps, Life prediction methods: Damage rate approach, Parametric-, Analytical- and Extrapolation methods Superplasticity. Phenomenological aspects, Types of Superplasticity, Superplasticity models: Topological and Microstructural, Superplastic materials and applications. Advanced topics in Creep. Advanced creep techniques, Creep at small length scales, Creep-Fatigue interaction, Low temperature creep plasticity, Zero-creep experiment, Creep in multiphase alloys. Case studies and Special topics. Creep failure of components from aerospace and nuclear power plants Creep and Superplasticity in non-equilibrium microstructures. Design of creep resistant materials, Creep data analysis. **Course references:** 1. F.R.N. Nabarro and H. L. de Villiers, The Physics of Creep, Taylor and Francis Ltd., 1995; 2. M. Kassner, Fundamentals of Creep in Metals and Alloys, Third Edition, Elsevier, 2015; 3. J-S. Zhang, High Temperature Deformation and Fracture of Materials, Woodhead Publishing, 2010; 4. J-P. Poirier, Creep of Crystals, Cambridge University Press, 2009; 5. K. Naumenko and H. Altenbach, Modelling of Creep for Structural Analysis, Springer, 2010.; 6. H.J. Frost and M.F. Ashby, Deformation-Mechanism Maps: The Plasticity and Creep of Metals and Ceramics, Pergamon, 1982; 7. C. T. Sims, N. S. Stoloff, W. C. Hagel, Superalloys II: High-Temperature Materials for Aerospace and Industrial Power, Wiley, 1987; 8. M.N. Shetty,

			Dislocations and Mechanical Behaviour of Materials, PHI Learning Pvt. Ltd., 2013.
MSE628	ELECTRONIC DEVICES AND CHARACTERIZATION	3-0-0-0-9	Electronic Device related characteristics of a semiconductor material Review: n and p type semiconductors, wafers, carrier mobility, conductivity, equilibrium carrier statistics, generation recombination processes and carrier transport, traps and defect states. Characterization: (a) Doping density: Secondary lon Mass Spectroscopy (SIMS). Resistivity: Four-point probe (c) Charge carrier type, density, mobility: Hall effect (d) Bandgap: UV-Visible spectroscopy (e) Absorption coefficient. Semiconductor-semiconductor junction: (a) PN junction in thermal equilibrium, I-V characteristics: qualitative, (b) PN junctions I-V characteristics of an ideal device, origin of non idealities, (c) Diode variants: solar cell I-V with illumination and bias effect and PIN diode, LEOs, (d) Device measurement of a solar cell (Light and dark I-V, R_s, R_{sh}, Efficiency), (e) BJTs: Principle and device measurement. Metal Semiconductor junction: (a) Schottky and Ohmic contacts, thermionic emission, Tunnelling, Schottky diodes, (b) Contact resistance: Two terminal; Four terminal technique, (c) Barrier height: From 1V, CV, Photocurrent; comparison of three. Capacitance Voltage measurements: Doping Density and majority carrier density profiling, Band offset for a semiconductor-semiconductor junction using CV technique, Metal insulator semiconductor junctions : (a) MOS capacitor, quantitative analysis of a flat band device, CV characteristics, MOS capacitor: deviations from flat band conditions, (c) Oxide charges : fixed, mobile, trapped and interface trapped charges, MOSFET: FinFET MOSFET: Architecture for creating simple Boolean logic, memory Dopant density profiling using CV (already discussed in section 3 above) **Course References:** 1. Semiconductor Material and Device Characterization, Dieter K. Schroder, January 2006,WileyIEEE Press; 2. Metal Semiconductor Contacts (Electrical & Electronic Engineering Monographs), E. H.Rhoderick and R. H. Williams, Oxford University Press, USA; 2nd edition (September I,1988); 3. Electronic Structure of Metal Semiconductor Contacts, Winfried Monch (Nov 30,I990)Springer; I edition (November 30, I990); 4.Optical Techniques for Solid State Materials Characterization, Rohit P. Prasankumar and Antoinette J. Taylor, CRC Press; I edition (July 5, 201I); 5. Semiconductor Device Fundamentals by Robert F. Pierret, Addison Wesley; 2nd edition(April 12, I996); 6. Advanced Semiconductor Fundamentals (2nd Edition) by Robert F. Pierret, Prentice Hall; 2 edition (August 19, 2002); 7. Semiconductor Devices: Physics and Technology, Simon M. Sze, MingK wei Lee,Wiley; 3 edition (May I5 , 20I2).
MSE629	PHYSICAL & MATHEMATICAL MODELLING OF STEELMAKING PROCESSES	3-0-0-0-9	Brief review of scientific fundamentals such as thermodynamics, kinetics and transport phenomena of relevance to steel making: Mathematical modelling techniques: Principles of physical modelling: Successful modelling examples including converter steel making, gas

			stirred ladles: Alloy addition kinetics, tundish operations and continuous casting.
MSE630	ADVANCES IN IRON AND STEEL MAKING	3-0-0-0-9	Recent trends in iron and steel making: Gas solid and slag metal reaction: Sponge iron making: Continuous steel making: Continuous casting: Vacuum degassing and electro slag remelting: Advances in agglomeration, blast furnace and steel making, analysis of iron and steel making processes and reactors: Deoxidation and impurity control: Emphasis on application of physical chemistry and transport phenomena.
MSE631	ELECTROCERAMIC MATERIALS AND APPLICATIONS	3-0-0-0-9	Introduction, FCC packed structures (MgO, CeO_2 etc), HCP packed structures ($LiNbO_3$ etc), Other structures such as Perovskite ($BaTiO_3$ etc) and Rutile structures, Defects in Elemental Solids and Ionic Compounds, Defect Classes, Point Defects, Kröger-Vink Notation, Point Defect Formation & Equilibrium, Law of Mass Action and electrical neutrality, Thermodynamics of Intrinsic Defects and Defect Reactions. Complexes Containing an Impurity Centre and an Ionic. Defect, Intrinsic Ionic Defect Associates and Effect of Impurities on the Concentration of Defect Complexes and Associate. Defect Equilibria in Pure and Stoichiometric Compounds with Schottky Defects, Frenkel Defect Pairs and Intrinsic Ionization of Electrons, **Course References:** 1 L. L. Hench and West, Electroceramics, Wiley; 2. D. M. Smyth; The Defect Chemistry of Metal Oxides; Publisher: Oxford University Press, ISBN10:01951101453; 3. Wei Gao and Nigel M. Sammes; An Introduction to Electronic and Ionic Materials; Publisher: World Scientific; 4. A.J. Moulson & J. M. Herbert; Eiectroceramics: Materials, Properties, Applications;, Publisher: Wiley; 5. M. W. Barsoum; Fundamentals of Ceramics; Publisher: Institute of Physics; 6. Impedance Spectroscopy: Theory, Experiment and Applications; Edited by J. Ross Macdonald & EvgenijBarsoukov, Publisher: John Wiley and Sons; 7. Robert Huggins;Use of defect equilibrium diagrams to understand minority species transport in solid electrolytes; Solid State lonics, 143 (2001) 316.
MSE634	FUNDAMENTALS OF SPRAY TECHNIQUES	3-0-0-0-9	Introduction Different Spray Techniques and their need Combustion Spraying: Flame Spraying, Thermal Spraying Techniques: High Velocity oxyfuel. Principle and Working Arc and Plasma Spraying: Wire/Powder Arc Spraying Plasma Spraying (Air/ Vacuum) Cold Spraying. Spraying Parameters Inflight conditions, Plasma Primary/ Secondary/ Carrier gases Power rating Feed rate Standoff distance Substrate preparation. Powder: Powder size and distribution Powder Injection Reaction of particles Coating Formation Evaporation/Condensation Comparison of deposition techniques Single Splat Formation Heat transfer and spreading of splat Splay layering and deposition Microstructure and densification of deposited coatings Diagnostics and Coating Reliability Thermal and Kinetic Profiles lnflight particle sensor Control of Deposition parameters Bulk Nanostructure and Near Net Shape Microstructural distribution Design and control of bulk nanostructure

			Mandrel choice Mandrel removal Lectures Case Studies: Thermal Barrier/ Ultra high temperature ceramics **Course References:** 1. Handbook of thermal spray technology, Joseph R. Davis, ASM International. Thermal Spray Society Training Committee (2004); 2. Advanced Structural Ceramics, Bikramjit Basu and Kantesh Balani, Wiley (2011). Will be supplemented with handout, and journal publication.
MSE637	NANOTRIBOLOGY AND NANOMECHANICS	3-0-0-0-9	Definition of micro/nano tribology Origin of tribology Measurement techniques Role of tribology in MEMS/NEMSN. Nanotribology: Measurement techniques and Concepts AFM/FFM Role of Surface roughness Friction, scratching/wear and lubrication Local deformation Nanoindentation Surface elasticity/viscoelasticity. Surface imaging, Friction and Adhesion Atomic scale imaging Friction: macro and microscale (Tomlinson thermal/geometric effects) Surface roughness Nanoscale friction Wear mapping Lubricated adhesion and friction Multi length scale Wear, Scratching Nano and microscale wear Microscale scratching; Insitu local deformation characterization Nanomachining Indentation Pico/Nano indentation Localised surface elasticity/viscoelasticity Load displacement curve, indenter geometry, stiffuess Boundary Lubrication Lubricants, monolayers Liquid thin films. Nanomechanics and Testing Instrumentation: AFM, SPM Bulge tests, acoustic/imaging methods Defect Nucleation Scaling Effects Length scale effect on hardness, yield strength Roughness and contact parameters Model, Adhesion friction, 2 body and 3 body deformation, ratchet mechanism Scale effect on wear Case Studies Ultrathin amorphous carbon films Self assembled mono layers (for controlling adhesion, friction and wear) Nanotribology and nanomechanics of magnetic storage devices/ NEMS/MEMS Biomaterial/ Biological samples. **Course References:** 1. Introduction to Micromechanics and Nanomechanics, Shaofan Li and Gang Wang World Scientific Publishing Company (2008); 2. Fundamentals of tribology, Ramsey Gohar, Homer Rahnejat Imperial College Press (2008); 3. Advanced Structural Ceramics, Bikramjit Basu and Kantesh Balani, Wiley (2011); 4. course materials will be supplemented with handouts, and journal publications.
MSE638	SYMMETRY AND PROPERTIES OF CRYSTALS	3-0-0-0-9	Introduction 1 Symmetries in 1D, 2D and 3D, Examples of patterns showing various, symmetries, Symmetries and Lattices in 2D space : Operations of Translation, Rotation and Reflection, standard symbols, Lattices and Unit Cells, Permissible rotational symmetries, Derivation of lattices: oblique, rectangular, centred rectangular, square, hexagonal Point Groups in 2D; 4 : Set of symmetry operations, Group Theory Essentials, Evolution of 2D crystallographic point groups, 2D Space Groups (Plane Groups) Glide Planes: combination of lattice translation and reflection, Derivation of all the 17 plane groups, Understanding the Plane Group entries in the International Tables, of

			Crystallography3D Point Groups 4 : Combination of rotation axes in 3D, Development of the 32 point groups, Laue Groups3D Bravais Lattices Addition of a third translation to the plane groups, Derivation of Bravais Lattices3D Space Groups Screw Axes: combination of lattice translation and rotation, Development of the 230 space groups, Understanding the Space Groups entries in the International Tables of Crystallography **Course Reference**: 1. M.J. Buerger, Elementary Crystallography; 2. International Tables of Crystallography A, International Union of Crystallography; 3. J. F. Nye, Physical Properties of Crystals (1995), Oxford Science Publications; 4. D.R. Lovett, Tensor Properties of Crystals (1999), Institute of Physics Publishing; 5. Robert E. Newnham; Properties of Materials: Anisotropy, Symmetry, Structure; Oxford Pr.
MSE639	INTERFACES AND MATERIALS PROPERTIES	3-0-0-0-9	Surfaces and interfaces play extremely important role in determining the physical properties of materials. These become of critical important especially when materials approach nanoscale dimensions such as in the form of thin films and nanostructures. The objective of this course is to provide the UG/PG students of MSE department a background on the nature of various interfaces (Solid-Vapour, Solid- Liquid and Solid-Solid), their thermodynamics, their interactions, nature of defect surfaces and domains. Special emphasis will be paid towards understanding of the homophase (e.g. grain boundaries) and heterophase systems (e.g. epitaxial films). As part of case studies, the contents will elucidate a few metal and ceramic interface systems vis-a-vis their impact on the functional properties. Finally, the students will be exposed to the surface modification techniques that affect these interfaces and their functionality. 1) Introduction to the interfaces: basic classification and definitions 2) Basics of Energetics Definitions and relations to physical properties; Broken bond model; Gamma plot, Wulff plot and construction of Solid-Vapour interfaces; Surface structure (Terraces, ledges and kinks) and defects; Surface relaxation and reconstruction Phase transformations; Crystal growth from vapour (Nucleation and Growth, Vicinal surfaces; Surface films 4) Solid-Liquid Interfaces; Structure and properties of liquids; Interfacial structure and energy Crystal growth; Solute partitioning and morphological stability; Electrical aspects of surfaces and surface chemistry such as electrical double layer, zeta potential 5) Solid-Solid Interfaces a) Tyesflsldiercesdbscs b) phase Interfaces; Grain boundary structure and energy; Types of grain boundaries and dislocation models; Stacking Fault and Twin Boundaries; Grain Boundary; Grain boundary and twin boundary equilibria; Domains in ferroelectric and ferromagnetic systems: energetic; c) Hetero-phase Interfaces; Interphase boundaries; Coherent and semicoherent interphase boundaries and their energetic; Roughening and Phase transformations on interphase boundaries; Antiphase Boundaries; Interfaces between differences materials and structures; Terrace-ledge and kink models; Growth, morphology and segregation at the heterophase interfaces 6) Interfaces and Functional Behaviour: Case Studies; Effect of interfaces in mechanical properties;

			Effect on the strength of materials; High temperature behaviour: Creep; Grain boundary engineering, sliding and migration; Fracture; metals and alloys: surface ;embrittlement, grain boundary; embrittlement, failure of ceramics and interface strengthening; Friction and adhesion; Electrical Properties; Role of interfaces in conduction in metals and ceramics; Interfaces effects in dielectrics, ferroelectrics and piezo electrics and their; thin films and hetero structures, domains and grain boundaries; Hetero structures; strain ;and epitaxy and their effects on functional behavior; Interface effects on the magnetic properties of bulk magnetic materials and thin film devices; Interfaces in optical devices with emphasis on the solar cells and displays 7) Surface modification and impact on properties. **Course references:** Interfaces in Materials: Atomic Structure, Thermodynamics and Kinetics of Solid-Vapor, Solid-Liquid and Solid-Solid Interfaces, James M. Howe, Wiley-Interscience; 2. Physics and chemistry of interfaces By Hans-gen Butt, Karlheinz Graf, Michael Kappl, Wiley-VCH; 3. Physics of surfaces and interfaces, H. Ibach, Springer; 4. Solid surfaces, interfaces and thin films, Hans Lüth, Springer; 5. Physical Chemistry of Surfaces, Arthur W. Adamson, Wiley-Interscience
MSE642	MICROSOPY AND MICROANALYSIS OF MATERIALS	3-0-0-0-9	Advanced Optical microscopy: Special microscopy techniques and applications: Bright field and dark field imaging; confocal microscopy; interference microscopy; polarized light microscopy; phase contrast microscopy. Scanning near field laser microscopy Image processing and quantification Scanning electron microscope: Basis of image contrast and various operating modes in SEM SE and BSE, Xray, EBIC, cathodoluminescence, voltage contrast mode, Magnetic contrast mode. Environmental SEM, Low voltage SEM, and applications. Electron back scattered diffraction /OM: Basic principles, the microtextural data acquisition and analysis, applications; Fractography and failure analysis. Transmission electron microscope: Wave properties of electrons, lens defects, aberration corrected TEM and sub-Angstrom resolution (2L) Origin of contrast: mass thickness contrast, diffraction contrast and crystal defect analysis. Dynamic diffraction and anomalous absorption effects, image artifacts (3L) BF, OF, Weak beam OF images and applications (I L) Electron Diffraction: SADP, Micro diffraction, CBED. Diffuse scattering and fine structure in Diffraction pattern. (2L) Phase contrast and HRTEM: Contrast transfer function and lattice imaging, Computer simulation of lattice and structural images, Interpretation of images and illustrative examples (2L) STEMHAADF imaging, information limit (lL) Lorentz microscopy and holography (1) Specimen preparation: Mechanical thinning, electrochemical thinning, ion milling, sputter coating and carbon coating, replica methods (2L) **Course References:** 1. Fundamental of light microscopy and electronic imaging, 0.8. Murphy, WileyLiss, 2001; 2. Microstructural Characterization of Materials D. Brandon and W.D. Kaplan, John Wiley

			and Sons,2008; 3. Scanning Electron Microscopy & XRay Microanalysis, J. Goldstein et.al, Springer, 2003; 4. Transmission Electron Microscopy B.D. Williams & C. B. Carter, Springer, 2009; 5. Science of Microscopy, P.W. Hawkes and J.C.H. Spen(:e, Springer, 2007; 6. Surface Analysis methods in materials science, Editors: D.J.O; Connor, B.A. Sextton, R.St. C. Smart, Springer, 2003; 7. Materials Characterisation Techniques, S. Zhang, Lin Li and Ashok Kumar, CRC Press, 2009; 8. Fundamentals of Materials Science: The microstructure property relationship using metals as model systems, E.J. Mittemeijer, Springer, 2010
MSE643	ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN MATERIALS ENGINEERING	3-0-0-0-9	Understanding the need of use of artificial intelligence and machine learning in Materials Science and engineering. The importance data and informatics in material design; Materials tetrahedron – correlation between processing with materials structure and subsequently on properties, mechanical and functional properties; Component level to atomic level aspects of material design, basic tools including – CALPHAD; Ab initio, Density Functional Theory (DFT), Monte Carlo (MC) or Molecular Dynamic (MD) followed Phase Field Simulations (PFM) for microstructural evolution; Essential Statistical Tools, Machine Learning, Deep Learning, Tensor flow, Advanced Deep Learning; Historical paradigms of advanced materials development; the critical need for these new approaches employing data sciences and informatics; connection between computational simulation and experiments to speed up the processes of materials discovery and development; Process-Structure-Property Linkages; Meaning of Materials Knowledge; role of Data Science in Materials Knowledge System; Overview approaches and main components of Data Science. Case Studies and project on use of ML and AI on problems of materials science and engineering. **Course References:** 1. Turab Lookman, Stephan Eidenbenz, Frank Alexander, Chris Barnes; Materials Discovery and Design: By Means of Data Science and Optimal Learning, Springer, 2108; 2. Yuan Cheng, Tian Wang and Gang Zhang, Artificial Intelligence for Materials Science, Springer, 2021; 3. Phil Del Luna, Accelerated Materials Discovery, De Grutyer, 2022

MSE645	ADVANCE CHARACTERIZATION TECHNIQUES FOR PHOTOVOLTAIC DEVICES AND MATERIALS	3-0-0-1-10	The photovoltaic principle: Light trapping, absorption, charge extraction, Recombination, The Shockley-Queisser theory, A general structure of a thin-film solar cell, Example of CdTe, CIGS, perovskite solar-cell operation, thin-film Si solar cell. Techniques based on current-voltage characteristics: Measurement of current-voltage curves, solar simulator, AM1.5G spectrum, V_{oc}, J_{sc}; Equivalent circuit model Recombination and ideality factor Two-diode model, Determination of series-resistance, shunt resistance, Temperature-dependent I-V measurements, Quantum efficiency (QE) measurements Measurement principle, external and internal QE Voltage-bias and illumination-bias dependent QE Effect of frequency of modulated light Interpretation of QE for some thin-film solar cells. Techniques based on capacitance spectroscopy: Admittance basics, sample requirement and instrumentation, Capacitance-voltage (CV) profiling and depletion approximation, Admittance response of deep-states and effect on CV profiling, DLTS, Admittance spectroscopy: bias, frequency and temperature dependence, Electric modulus spectroscopy accompanied by illumination, Drive level capacitance profiling, Photocapacitance: transient, deep level optical spectroscopy. Electroluminescence analysis of solar cells and solar modules: Spatially and spectrally resolved electroluminescence; Photoluminescence spectroscopy: TRPL, temperature dependence, bias dependence, examples of its application to cells. Soft X-ray and electron spectroscopy: Band alignment at interface, probing the chemical surface structure. Techniques for individual material characterization: Scanning probe microscopy, Raman spectroscopy, laser induced modification Raman spectroscopy, Techniques for elemental distribution profiling, Electron microscopy techniques: Backscatter imaging, electron-beam induced current, cathodoluminescence. Case studies involving established thin-film solar cells and role of characterization technique that provided insight into various process and ultimately to their improvement. **Course references:** 1. Advance Characterization Techniques for Thin Film Solar Cells edited by D. A-Ras, T. Kirchartz, U. Rau; Wiley-VCH, 2. Semiconductor Materials and Device Characterization" by D. K. Schroder; Wiley-Interscience, 3. "Thin-Film Solar Cells: Fabrication, Characterization and Applications" edited by J. Poortmans and V. Arkhipov; Wiley series in materials for electronic and optoelectronic applications.
MSE646	X-RAY CRYSTALLOGRAPHY - I	3-0-0-0-9	Elemental compound and alloy crystals, modes of bonding, crystal types, density of packing, atomic stacking, inter atomic voids, coordination polyhedra, Paulings rules, symmetry elements, space and point groups, group theoretical formulation, diffraction or radiation.
MSE647	ADVANCED SECONDARY STEELMAKING AND	3-0-0-0-9	Concept of alloying and cleanliness of steel, non-metallic inclusions and dissolved gases, sources of inclusions, sulfur, phosphorous and tramp

	SPECIAL STEELMAKING		elements in steel. Primary steel, scrap, ferro-alloys, fluxes, powders, deoxidizers, injection of desulphurizing agents. Thermodynamics of desulphurization and degassing, Slag-metal equilibria; Kinetics of desulphurization and degassing. Role of slag and powders inclusion control, Modification of inclusion morphologies. Electric Arc Furnace, Induction Melting, and Vacuum Induction Melting. Ladle Metallurgy: Inert gas stirring, Vacuum degassing, CAS/CAS(OB), Ladle furnace, Transport phenomena in ladle, Degassing: Vacuum Degassing, RH Degassing, Vacuum Arc Degassing, Tundish Metallurgy: Transport phenomena in tundish and evaluation of tundish hydrodynamic performance. Argon Oxygen Decarburization, Vacuum Oxygen Decarburization. Vacuum Arc Remelting, Electroslag Remelting. Continuous, Ingot and Near-net-shape casting. **Course References:** 1. Secondary Steelmaking: Principles and Applications, Ahindra Ghosh, CRC Press, 2003; 2. Modelling of Steelmaking Processes, Dipak Mazumdar, James W. Evans, CRC Press, Taylor and Francis, 2009; 3. The Making, Shaping and Treating of Steel, Steelmaking and Refining Volume, Ed. Richard J. Fruehan, The AISE Steel Foundation, 1998; 4. ASM Specialty Handbook: Stainless Steels, Ed. J.R. Davis, ASM International, 1994; 5. Extractive Metallurgy Vol. 3, Processing Operations and Routes, Alain Vignes, Wiley, 2011
MSE648	DIFFUSION IN SOLIDS	3-0-0-0-9	Diffusion equations and mathematical solutions: Phenomenological diffusion theories: atomic theory of diffusion, theoretical and experimental investigation of diffusion phenomena: Diffusion in ionic solids and semiconductors: Grain boundary and surface diffusion, thermal and electro diffusion.
MSE650	FUNDAMENTALS OF STEREOLOGY & APPLICATIONS TO MICROSTRUTURAL ANALYSIS	3-0-0-0-9	Concepts and language of stereology; geometrical probability; fundamental operations in stereology; averaging with respect to orientation; basic stereological parameters on true 2D sections and thick sections; topological parameters of microstructure; error analysis; applications of analysis of optical, scanning and transmission electron micrographs; numerical density and size distribution of particles and grains of various shapes and sizes; stereological analysis of anisotropic microstructures; fractal description of various microstructures; fractal dimensions and its significance; applications to characterization of martensitic, polycrystalline and other structures and fracture surfaces.
MSE652	NANOCOMPOSITE THIN FILMS AND APPLICATIONS	3-0-0-0-9	Crystal structures of thin films, Defects in thin films (vacancies and interstitials, dislocations etc.), Nanocrystalline, polycrystalline and epitaxial thin films, Thermal dynamics and diffusion, Interface and surface of thin films, Thin film nucleation and growth models (2D, 3D, and 2D-3D combination), Thermodynamics of thin film growth, Epitaxy: Homoepitaxy and heteroepitaxy, Lattice matching epitaxy and domain matching epitaxy, Superlattice structures, Strain Engineering, Characterization of epitaxial Thin Films and Surfaces

			(XRD, SEM, TEM, SPM, Ellipsometry, XPS), Vacuum science and technology, Sputtering, Pulsed Laser Deposition (PLD), Thin film metal oxides, Growth of self-assembled nanocomposites, Oxide-oxide and oxide-metal nanocomposites, vertically aligned nanocomposites, strain compensation model, Lattice mismatch between two phases, Heckmann Diagram, Functionality coupling, Ferroelectricity, Si integration, Ferromagnetism, Magneto-electric coupling, Magneto-optical coupling, Light-Matter interaction, Metamaterials, Optical sensing, Morphological control of nanocomposite thin films and functionality tuning. **Course References:** 1. Materials Science of Thin Films: Deposition and Structure, by M. Ohring, 2002; 2. Electronic Thin Film Science for Electrical Engineers and Materials Scientists, by K-N Tu, J.W. Mayer and L.C. Feldman, 1992; 3. Elements of X-ray Diffraction, 2nd Edition, by B.D. Cullity, 1978.
MSE653	TRANSMISSION ELECTRON MICROSCOPY & NANO-ANALYSIS OF MATERIALS	3-0-0-0-9	1. Introduction: History, Interaction of electrons with matter, Different kinds of TEMs; 2. Electron scattering and diffraction: Terminology of scattering Interaction cross section; concept of mean free path; Scattering in the TEM; Fraunhofer and Fresnel diffraction; electron diffraction patterns; 3. Elastic and inelastic scattering in TEM: Elastic scattering mechanisms; scattering at isolated atoms, atomic scattering factor, the structure factor, simple diffraction concepts. Inelastic processes occur in the tern; 4. Diffraction in TEM and diffraction techniques: diffraction in the tern and dynamical effects; practical aspects of diffraction pattern formation; reciprocal lattice, vector g, Ewald sphere of reflection; excitation error; diffraction from long period super lattices, small volumes, wedge shaped specimens, planar defects, particles, dislocations, etc. CBED patterns, comparing sad and CBED. **Course References:** 1. Transmission Electron Microscopy B.D. Williams & C.B.Carter, Springer, 2009; 2. Aberration corrected analytical transmission electron microscopy, Ric Brydson, Wiley, 2011; 3. Analytical electron microscopy for materials science, D. Shindo and T. Oikawa, Springer, 2002; 4. Introduction to conventional electron microscopy, Marc De Graef, Cambridge University Press, 2005; 5. Science of Microscopy, P.W. Hawkes and J.C.H. Spence, Springer, 2007; 6. Insitu electron microscopy at high resolution, Editor: Flrian Banhart, World Scientific, 2008; 7. Materials Characterisation Techniques, S. Zhang, Lin Li and Ashok Kumar, CRC Press, 2009; 8. Handbook of Microscopy: Applications in materials science, solid state physics and chemistry. Edited By: S. Amelinckx, D. van Dyck, J. van Landuyt, ad G. van Tendeloo, VCH, Weinheim, 1997; 9. Microstructural Characterization of Materials D. Brandon and W.D. Kaplan, John Wiley and Sons,2008

MSE654	ADVANCED CORROSION SCIENCE AND TECHNOLOGY	3-0-0-0-9	Impact of corrosion on industry and environment. Corrosion - definition, electrochemical equilibrium between metal and solution. Derivation of electrochemical driving force for electrochemical dissolution of pure metal using thermodynamic principles. Introduction to Nernst's law. EMF series. Effect of activity on driving force for corrosion. Introduction to Eh-pH diagrams for metals. Construction of Eh-pH diagrams for metals using thermodynamic data. Application of these diagrams to predict various electrochemical states of a given metal in aqueous media. Assignments on Eh-pH diagrams. Introduction to polarization at metal-solution interface. Reaction steps involved in an electrochemical corrosion of metals in aqueous media. Exchange current density as a fundamental kinetic parameter. Overpotential vs polarization, Relationship between overpotential and current density across metal-solution interface. Activation and concentration polarization. Mixed potential theory and Evan Diagrams. Metallurgical and environmental factors influencing corrosion. Forms of corrosion: Uniform attack versus localized corrosion, galvanic corrosion, intergranular corrosion, pitting, crevice corrosion. Forms of corrosion: Erosion corrosion, Stress corrosion cracking, hydrogen induced damage, corrosion fatigue. Corrosion in Mining and marine environments. Metal-Microbe Interactions and Biofouling Microbially Induced Corrosion – mechanisms. Corrosion in acids and alkalis; Corrosion by industrial corrosive pollutants – A generalized model, High Temperature Corrosion Oxidation – thermodynamic and kinetic principles. Molten salt and liquid metal embrittlement – mechanisms. Assignments on microbially induced corrosion and high temperature oxidation. Techniques for Corrosion monitoring and assessment. Conventional Electrochemical techniques – DC and AC analysis. Recent advances in corrosion testing. Materials Design and Selection, Corrosion mitigation – conventional methods and recent advances. **Course References:** 1. Principles and Prevention of Corrosion, Denny A. Jones, Prentics Hall, 1996; 2. Corrosion Engineering: Principles and Practices, Pierre R. Roberge, The McGraw-Hill, 2008; 3. Uhlig's Corrosion Handbook, R. Winston Revie, The Electrochemical Society Inc. and John Wiley and Sons Inc. 2011.
MSE655	MODERN TRENDS IN METAL FORMING PROCESESS	3-0-0-0-9	Limitation of conventional metal forming methods: Powder rolling and its various variants, spray rolling, direct strip process: Powder, spray, rotary and isothermal forging: Hydrostatic and powder extrusion: Conform process: Applications of these processes for making conventional and speciality products.
MSE657	DEFORMATION PROCESSING	3-0-0-4-13	Slip planes and systems in various crystal systems; Elasticity and Plasticity; Deformation processes including Rolling; Forging, Extrusion; Drawing and deep drawing etc.; Deformation of plastics and polymers; superplasticity; Formability; Failures; Friction wear and lubrication

			Course References: 1. Hosford, W. F., and Cadell, R. M., 2007, Metal Forming: Mechanics and Metallurgy, Cambridge University Press, Cambridge; 2. George Dieter, 1986, Mechanical Metallurgy, McGraw Hill.
MSE658	DISLOCATIONS AND PLASTICITY	3-0-0-0-9	Overview of defects in Materials: (point, line, planar and volume defects) and their classification. Overview of plastic deformation mechanisms. Point defects: interaction and distributions, statistical thermodynamics, role in diffusion and deformation. Basic understanding of dislocations using physical and computer models: the Volterra cut, Burger’s vector and the Burgers circuit, the line vector, edge, screw and mixed locations, Role of dislocations in weakening the crystal and in plasticity. Elasticity theory of dislocations: Stress, strain and displacement fields and energy of a dislocation, Forces on dislocations (including image force) Interaction between dislocations, Core of a dislocation. Motion of dislocations: The Peierls stress, role of the core structure, interaction of dislocations with other defects (including yield point phenomenon); kinks; jogs; cross slip; climb, Temperature and strain rate dependence of flow stress, Dislocation dynamics and the tensile stress strain curve. Dislocations in FCC Metals: Partial dislocations (Shockley and Frank partials) stacking faults, Thompson’s tetrahedron, Lomer-Cotrell sessile dislocation. Overview of dislocations in other crystal structures: HCP metals, BCC metals, ionic crystals, super lattices, covalent crystals. Origin and multiplication of dislocations: dislocations in freshly grown crystals, nucleation of dislocations, multiplication of dislocations (by Frank-Read sources, cross slip and climb), Grain boundary sources, Recovery and recrystallization. Geometrically/structurally necessary dislocations: low angle & general grain boundaries, indentation, interfacial dislocations, Twinning including incoherent twins. Specific examples of role of dislocations and case studies: Dislocations in nanocrystals, The Hall Petch relation and the Inverse Hall Petch Effect (IHPE), Dislocations in epitaxial systems, Severe Plastic deformation, Role of dislocations in Creep, Fatigue and Fracture. **Course References:** 1. Introduction to Dislocations, D. Hull and D.J. Bacon, Pergamon Press, Oxford, 1984; 2. Theory of Dislocations, J. P. Hirth and J. Lothe, McGraw-Hill, New York, 1968; 3. Crystal Defects and Crystalline Interfaces, W. Bollmann, Springer Verlag, Berlin, 1970; 4. Elementary Dislocation Theory, J. Weertman and J. Weertman, The MacMillian Company, New York, 1964; 5. http://www.tf.unikiel.de/matwis/amat/def_en/
MSE659	POWDER METALLURGY	3-0-0-0-9	Powder Production (Chemical Methods, Electrolytic Methods, Atomization, Mechanical Methods),Powder Characterization (Chemical Composition and Structure, Particle Size and Surface Topography, Pyrophoricity and Toxicity), Powder Compaction, Phenomenological Aspects of Sintering, Solid State Sintering, Analytical Approach to Sintering, No Isothermal Sintering, Microstructural

			Evolution, Liquid Phase Sintering, Stages of Liquid Phase Sintering, Super solidus Sintering, Activated Sintering, Pressure Assisted Sintering, Microwave Sintering, Select Case Studies. **Course References**: 1. R.M. German, Powder Metallurgy Science, ed. John Wiley, 1999; 2. A. Upadhyaya, G.S. Upadhyaya, Powder Metallurgy: Science, Technology and Materials, 2011; 3. ASM Handbook, Volume 7: Powder Metal Technologies & Applications (1998)
MSE661	FRACTURE, FATIGUE AND CREEP: MATERIALS AND MODELS	3-0-0-0-9	Stress concentration and stress concentration factor, Fracture modes: Mode I, Mode II, and Mode III, Fracture Mechanics: Energy approach and Stress intensity factor approach; Linear elastic fracture mechanics (LEFM), Plane strain and plane stress, Plastic zone size, KIC (fracture toughness), Ductile and brittle fracture, Transgranular and intergranular fracture, statistical analysis of failure strength; Modelling methods; Basics concepts in fatigue and fatigue failure; Low and high cycle fatigue, S-N curve, Effect of notch on fatigue life, Stress and strain based approach; Fatigue crack initiation and propagation mechanisms, Fatigue crack growth rate and measurement techniques, Fatigue crack growth models, Fatigue Crack Closure, Two parameters approach – ΔK_{th} vs. K_{max}, Fatigue in Ceramics, Polymers and composites, Modelling methods for Fatigue and Fatigue resistant designs; Fundamentals of creep and activation energy, Creep and stress rupture tests, Superplasticity, superplastic materials and application, Deformation mechanisms at elevated temperature; Deformation mechanism maps; parametric relationships; Creep in metallic alloys (solute drag) and precipitation strengthened metals, Threshold stress analysis Creep resistant materials: Nickel- and Co- based superalloys; high temperature Steels, materials for aerospace and nuclear technologies. Creep of intermetallic, polymers, ceramics and composites. Modelling methods for creep and creep failures; Examples of fatigue and creep failures in history, Environmental assisted fracture, Use of X-ray tomography (3D/4D studies), Small length scale fatigue and creep (nanoindentation, pillar compression)
MSE662	ELECTRONIC AND METALLURGICAL WASTE RECYCLING	3-0-0-0-9	Understanding the 5 R’s (Refuse, Reduce, Reuse, Repurpose and Recycle) in the modern scenario. Types of electronic and industrial wastes. Appreciating the importance of classification and how it impacts the method of recycling. Categorization of types of wastes. Examples of battery sorting and separation from bulk electronic waste. Unit operations required for pre-treatment of electronic and industrial wastes. Importance of comminution in recovering valuable materials from industrial wastes. Examples of the material separation and enrichment of raw materials. Application of pyrometallurgy, hydrometallurgy and electrometallurgy for the recycling of metallurgical wastes. Fusion of these methods for efficient metal recovery. Metal recovery from leach liquor by electrowinning, solvent extraction, coprecipitation, ion exchange. Understanding methods of

			metal refining: fire refining, zone refining and electrolytic refining. Utilization of recovered materials for conventional applications, like casting of metals, production of refractories etc. Case studies on Waste Printed Circuit Boards and Integrated Circuits. Delamination of the WPCBs by dissolution of epoxy resin, separation of the copper matrix from glass fibre, leaching of the powdered WPCBs for extraction of metallic values like Cu, Ag, Au, Pt, Pd. Solder mask recovery from WPCBs. Numerical insight on recovery of metallic values from the leach liquor by solvent extraction, cementation. Case study on waste battery recycling: Significance and application of various batteries- Ni-Cd type batteries, Li-ion batteries, and other batteries. Separation of anodes, cathodes, and binders. Recovery of metals from battery shells. Utilization of spent electrodes for development of fresh batteries. Numerical insight on efficient recovery of metallic values from the electrode waste. Aluminium industry wastes: dross, red mud, spent pot linings, Salt Slag. Copper industry wastes: Smelter slags, Raffinate after leaching and solvent extraction, spent electrolyte after winning. Zinc industry wastes: Zinc ash, dross, flue dust and scraps. Iron and Steel industry waste: Ironmaking slag, steelmaking slag, wastewater treatment. Energy recycling, Environmental impact of recycling and Economics involved in recycling. **Course references:** 1. Resource Recovery and Recycling from Metallurgical Wastes, Ed: S. Ramachandra Rao, waste Management Series, 7, Elsevier B.V., Amsterdam, The Netherlands, 2006; 2. Electronic Waste Recycling Techniques, Hugo Marcelo Veit and Andrea Moura Bernardes, Topics in Mining, Metallurgy and Materials Engineering, Springer International Publishing Switzerland, 2015; 3. Electronic Waste Management, R. E. Heister and R. M. Harrison, Issues in Environmental Science and Technology, 27, RSC Publishing, Cambridge, UK, 2009.
MSE663	ELECTRICAL AND MAGNETIC PROPERTIES OF CERAMIC MATERIALS	3-0-0-0-9	Structure of oxides: Ionic diffusion in oxides: Defect structure of nonstoichiometric compounds: Conductivity dependence on partial pressure of oxygen: Macroscopic characterization of dielectric materials: Electronic, atomic dipole, space charge polarization: Relaxation phenomenon adiabatic equations: Ferroelectrics: Diamagnetism, paramagnetism and ferromagnetism, exchange ferromagnetic domain: Structure and properties of ferrites.
MSE664	SOLID STATE IONICS	3-0-0-0-9	Perfect Structure, Defects in Elemental Solid and Ionic Compound, Defect Classes, Point Defects, Kröger-Vink Notation for Point Defects, Point Defect Formation & Equilibrium, Law of Mass action, Thermodynamic Related to Intrinsic Defects and Defect Reactions. Complexes Containing an Impurity Centre and an Ionic Defect, Intrinsic Ionic Defect Associates and Effect of Impurities on the Concentration of Defect Complexes and Associate. Basic Concepts of Diffusion, Tracer Diffusion, Self-Diffusion, Chemical Diffusion, Ambipolar Diffusion, Ionic Conduction in Crystalline Solid, Intrinsic and Extrinsic Ionic Conduction,

			Transference Number, Nernst Einstein Relationship, and Conductivity Diffusion Relationship. Defect Equilibria in Pure and Stoichiometric Compounds with Schottky Defects, Frenkel Defect Pairs and Intrinsic Ionization of Electrons, Defect Equilibria in Nonstoichiometric Oxides such as Oxygen Deficient Oxide, Oxide with excess Metal, Metal Deficient Oxide, Metal Oxide with Excess Oxygen. Brouwer Diagrams for YSZ, Undoped and Doped Ce02, Ti02 and BaTi03 Electrical Characterization Techniques such as AC Electrochemical Impedance Spectroscopy, Four Point Probe D.C. Method, Van Der Pauw Method, IV Curves, Blocking Electrodes, and Hebb Wagner Method. Open Circuit Potential, Efficiency, Nernst Equation Analysis, Activation Losses (Tafel Equation), Ohmic Losses, Concentration Losses. Description of Operation, Configurations, Cell Components, Materials Requirements, Manufacturing Techniques, and Performance of the following electrochemical devices such Solid Oxide Fuel Cells, Gas Sensors and Batteries. **Course References:** 1. 1.D. M. Smyth; The Defect Chemistry of Metal Oxides, Publisher: Oxford University Press; 2. A.J. Moulson & J. M. Herbert; Electroceramics: Materials, Properties, Applications, Publisher: Springer; 3. M. W. Barsoum, Fundamentals of Ceramics, Publisher: Institute of Physics; Impedance Spectroscopy: Theory, Experiment and Applications, Edited by J. Ross Macdonald & Evgenij Barsoukov, Publisher: John Wiley and Sons; 5. Robert Huggins;Use of defect equilibrium diagrams to understand minority species transport in solid electrolytes, Solid State Ionics, 143 (200 I) 316; 6. CRC Handbook of Solid State Electrochemistry; Edited by P. J. Gellings & H. J. M. Bouwmeester, Publisher: CRC Press; 7. High Temperature Solid Oxide Fuel Cells, Fundamental, Design and Applications , Edited by Subhash C. Singhal & Kevin Kendall, Publisher: Elsevier
MSE665	PRACTICAL TRANSMISSION ELECTRON MICROSCOPY & NANOANALYSIS OF MATERIALS	3-0-0-0-9	Specimen preparation for TEM analysis: Metallic self-supporting samples. Electropolishing Ceramics and electronic devices: Cross sectional specimen preparation. Ion Milling: Soft materials, polymers, biological specimens: Ultramicrotomy. Powders, Nanoparticles, fibres, fragments. Focused Ion Beam techniques. Importance and use of Plasma Cleaners. TEM: Instrumental details and requirements: Physics of Different Electron Sources: Lenses, Apertures and Resolution: Electron Detection Display and Image Recording Pumps and Holders Operating modes, Illumination System, alignment and aberration correction calibrations: Forming DPs and Images; STEM Imaging System: Alignment and Stigmation. Lens Rotation Centers, Correction of Astigmatism in the Imaging Lenses, Calibrating the Imaging System; Magnification Calibration, Camera Length Caltbration;Electron Diffraction and diffraction techniques: Practical aspects of diffraction and diffraction pattern analysis Mathematical Definition of the Reciprocal Lattice; Laue Equations and their Relation to Bragg's Law, Ewald Sphere of Reflection; The Excitation Error Experimental SAD Techniques, Indexing Single Crystal DPs, Ring Patterns from

			Polycrystalline Materials, Hollow Cone Diffraction, Amorphous Materials Precession Diffraction, Double Diffraction, Orientation of the Specimen, Orientation Relationships Amplitude contrast imaging and image interpretations : Image artifacts in TEM Systematic Crystal defect analysis: Dislocation analysis, stacking fault analysis, Grain boundaries and Interphase interface boundaries Volume Defects and Particles **Course References:** 1. Transmission Electron Microscopy B.D. Williams & C.B.Carter, Springer, 2009; 2. Sample preparation handbook for TEM: Methodology, J. Ayache et al., Springer, 2010; 3. Sample preparation handbook for TEM: Techniques, J. Ayache et al., Springer, 2010; 4. Aberration corrected analytical transmission electron microscopy, Ric Brydson, Wiley, 2011; 5. Analytical electron microscopy for materials science, D. Shindo and T. Oikawa, Springer, 2002; 6. Handbook of Microscopy: Applications in materials science, solid-state physics and chemistry. Edited By: S. Amelinckx, D. van Dyck, J. van Landuyt, ad G. van Tendeloo, VCH, Weinheim, 1997; 7. Microstructural Characterization of Materials D. Brandon and W.O. Kaplan, John Wiley and Sons,2008.
MSE666	SCIENCE AND TECHNOLOGY OF MAGNETIC MATERIALS	3-0-0-0-9	Magnetic units: Magnetic moments: Dia, para and Pauli paramagnetism, Molecular field: Ferro, antiferro and ferrimagnetism: Alloying effect on transition metals and intermetallics: Stability of domain structure: Origin of magnetic anisotropy and its application: Effect of inclusions, internal stress, magnetostriction and preferred orientation on magnetization: Susceptibility and coercivity calculations: Magnetic thin films, amorphous and crystalline, soft and permanent magnets: Technological aspects of magnetic materials.
MSE667	SELECTION AND DESIGNING WITH ENGINEERING MATERIALS	3-0-0-0-9	Overview of the design process: concepts and stages of engineering design and design alternatives to develop materials with tailored properties; Performance indices of materials; function, objective and constraints in design, specific stiffness limited and strength limited design for maximum performance, Performance indices for thermal, mechanical, thermomechanical applications, damage tolerant designs for structural applications; Basic concepts of materials science: processing structure property performance correlation; overview of conventional and advanced materials; Brief overview of the elements of chemical bonding, crystal structure, defect structure of different material classes, Brief introduction to the manufacturing processes for metals, polymers, ceramics, glasses and composite materials; design for manufacturability, Ashby’s material property charts; Decision matrices and decision matrix techniques in materials selection, relationship between materials selection and processing; Case studies: designing of Metals and alloys, ceramics and glasses, composite materials (MMC,CMC and PMC/ FRC) for specific applications.
MSE668	MATERIALS FOR BIOMEDICAL APPLICATIONS	3-0-0-0-9	Introduction to basic concepts of Materials Science; Salient properties of important material classes; Property requirement of biomaterials; Concept of biocompatibility; cell material interactions and foreign body

			response; assessment of biocompatibility of biomaterials. Important bimetallic alloys: Ti-based, stainless steels, CoCrMo alloys; Bioinert, Bioactive and bioresorbable ceramics; Processing and properties of different bioceramic materials with emphasize on hydroxyapatite; synthesis of biocompatible coatings on structural impant materials; Microstructure and properties of glassceramics; biodegradable polymers; Design concept of developing new materials for bioimplant applications.
MSE669	FIELD ASSISTED PROCESSING OF CERAMICS	3-0-0-0-9	Introduction and brief history of ceramic processing. Overview of the course, introduction to some useful softwares for term paper selection. Brief introduction on Ceramic fabrication processes, Powder metallurgy, additive manufacturing, sintering, and advancement in new processing methods (Course overview). Powder preparation and sintering. High voltage effects. Low voltage high current processing. Microwave processing. Direct electric field assisted sintering. Pressure assisted sintering. Additive manufacturing. Case studies, term paper review, group project. **Course references:** Carter, C. B., & Norton, M. G. (2007). Ceramic materials: science and engineering (Vol. 716, p. 712). New York: springer
MSE670	SOLIDIFICATION PROCESSING	3-0-0-0-9	Thermodynamics of solidification, Nucleation and growth, Pure metal solidification, Gibbs Thomson effect, Alloy Solidification: Mathematical Analysis of redistribution of solute during solidification, Constitutional undercooling, Mullins-Sekerka instability, Dendritic growth , Multi phase solidification: eutectic and peritectic, Structure of casting and ingots, Types of casting, Heat transfer, Design of riser and gating, Joining, different joining processes, Fusion welding, Solidification, heat transfer, fluid flow during fusion welding, Modelling of solidification under different conditions **Course References :** 1. Solidification Processing; Fleming, M.C., McGraw-Hill, N.Y., 1974; 2. Solidification of Casting; Ruddle, R.W., Institute of Metals, 1957; 3. Solidification and Casting, Davies, G.J., John Wiley and Sons, 1973; 4. Science and Engineering of Casting Solidification; Stefanescu, D.M., Kluwar Publications, 2002; 5. Fundamentals of Solidification by Kurz, W. and Fisher, D.J.,TransTech Publications, Switzerland,1989; 6. Applied Welding Engineering: Process, Codes and Standard; R.Singh,. Elsevier Inc.,2012
MSE671	HEAT TREATMENT AND SURFACE HARDENING	3-0-0-0-9	Introduction, Theory of Heat Treatment, Heat Treatment Environment, Different Heat Treatment Techniques, Fundamentals and Properties; Annealing, Tempering, Hardening, Thermo mechanical treatment, Fundamentals of Surface Hardening Treatment, Carburizing, Carbonitriding, Nitriding, Modern surface hardening techniques; Economy of Heat Treatment Processes **Course References:** 1. Principles of Heat Treatment of Steels by R.C. Sharma; 2. The, Heat Treating Source Book, ASM, 1986; 3. Heat Treatment of Metals by W.S. Owen (1963) (Institute for Metallurgists);

			4. Engineering Physical Metallurgy and Heat Treatment by Y. Lakhtein (Mir Publisher); 5. Phase Transformations in Metals and Alloys by D.A. Porter and K.E. Easterling (Taylor andFrancis)
MSE672	INTRODUCTION TO LIGHTWEIGHT ALLOYS FOR AUTOMOBILE APPLICATIONS	3-0-0-0-9	This course will discuss design of various alloys used in automobile with the aim of reduction in overall weight of a vehicle.
MSE673	FUNDAMENTAL AND APPLICATIONS OF ELECTROCHEMISTRY	3-0-0-0-9	Introduction: Electrochemical cell and reactions, Electrode potential, Galvanic and Electrolytic cells. General Electrochemical Concepts (I): Faradaic and Non-Faradaic Processes in Electrode, Ideal Polarized Electrode, Charge and Capacitance of Electrode, Electrode Double Layer, Double-layer capacitance and charging current in electrochemical measurements, Current-voltage characteristics of charge-transfer reactions, Factors affecting electrode reaction rate and current, Working, Reference & Counter electrodes. General Electrochemical Concepts (II): Mass-transfer controlled reactions, Modes of mass transfer, Semi-empirical treatment of steady-state mass transfer and transient response, Limiting current & Concentration polarization. Thermodynamics of Electrochemical Reactions: Reversibility, Gibbs free energy, Electric motive force (emf), Half-reactions, Reduction potentials, Concentration dependence of emf, Interfacial potential differences, Electrochemical potentials, Formulation of a cell potential. Kinetics of Electrochemical Reactions: Homogeneous kinetics, Arrhenius equation, Transition state theory, Tafel equation and plots, Exchange current, Butler-Volmer formulation of electrode kinetics, Approximate forms of current-overpotential equation, Reversible reactions with fast kinetics and effects of mass transfer. Electrochemical Techniques: Potential Step Method, Linear Potential Sweep and Cyclic Voltammetry, Impedance Spectroscopy, Bode and Nyquist Plots, Equivalent Electric Circuit Models. Batteries: Principle of Battery, Type of Electrode Reaction Mechanisms, Charge Capacity, Maximum Theoretical Specific Energy, Charge-Discharge Characteristics, Dependence of potential on the composition in both Binary and Ternary Electrodes, Case Study of Lithium/Iodine Cell, The shape of discharge curve and Gibbs Phase rule, The Coulometric Titration technique, Insertion Reaction Electrodes, Convertible Reaction Electrodes, Li-ion and Na-ion Batteries. Solid Oxide Fuel Cells: Principle of SOFCs, Defects in Ceramics, Materials for Anode, Cathode & Electrolyte, Charge-Voltage Characteristic in SOFCs and Polarization Losses. Corrosion: Types of corrosions, Corrosion protection, Mixed potentials, Corrosion rates and Polarisation curves.

			Course references: 1. Electrochemical Methods – Fundamentals and Applications; A. J. Bard and L. R. Faulkner; John Wiley & Sons, New York, 2nd Ed. (2001); 2. Advanced Batteries, Materials Science Aspects; R. A. Huggins; Springer, New York, (2009); 3. The CRC Handbook of Solid State Electrochemistry, Edited by P.J. Gellings and H.J.M. Bouwmeester; 4. Electrochemistry: Principles, Methods and Applications, C.M.A. Brett and A.M.O. Brett, Oxford University Press, Oxford; 5. Fuel cell Systems Explained, 2nd E. J. Larminie and A. Dicks, John Wiley & Sons, Inc.; 6. Additional reference and supplemental material to be supplied via Blackboard.
MSE674	DESIGN OF SINTERED PRODUCTS	3-0-0-0-9	Factors affecting design materials and geometry: Specific design of products like permeable materials, structural parts, bearings and cutting tool materials: conditioning of metal powders to influence processing parameters: Product properties evaluation and their standardization.
MSE675	SURFACE ENGINEERING	3-0-0-0-9	Introduction to surface of solids: structure, morphology, energy, types and classification. Surface dependent engineering properties: physical, chemical and mechanical. Common surface-initiated engineering failures and their mechanism: wear, friction, fatigue, corrosion, oxidation. Importance of surface engineering, Classification and scope of surface engineering of alloys and components, Methods and principles of surface modification of materials. Conventional surface modification methods: shot peening, flame hardening, induction hardening, carburizing, nitriding, diffusion assisted surface alloying, etc. Surface coating techniques by chemical/electro-chemical routes: electro/electroless deposition, anodizing, micro-arc oxidation. Surface coating by physical routes: thermal/plasma spray, physical vapor deposition, sputtering, ion plating, plasma ion implantation, hot dipping, galvanizing etc. Advanced surface modification methods: laser, plasma, ion and electron beam assisted surface engineering. Practical examples and case studies of surface engineering practices in industry. **Course references:** 1. Surface Engineering for Wear Resistances (Introduction and classification of Wear), By: K.G. Budinski, Prentice Hall, Englewood Cliffs, 1988; 2. Surface Engineering & Heat Treatment (Diffusion assisted surface alloying), By: P.H Morton, I.I.T, Brookefield, 1991; 3. Corrosion Engineering (classification of Corrosion), By: M.G. Fontana, M.C. Graw Hill, N. York, 1987; 4. Metals Handbook, Ninth Edition, Vol.5, Surface Cleaning, Finishing & Coating, ASM, Metals Park Ohio, 1982; 5. ASM Handbook, Vol. 5A, Thermal Spray Technology, Metals Park Ohio, 2013; 6. Materials Science and Engineering by W. D. Callister; 7. Introduction to Surface Engineering and Functionally Engineered Materials, by Peter Martin, WILEY (ISBN: 978-0-470-63927-6), 2011; 8. Surface Engineering of Metals: Principles, Equipment, Technologies, by: Tadeusz Burakowski, Tadeusz Wierzchon, CRC Press, 1988; 9. Surface Engineering for Corrosion and Wear Resistance, by JR

			Davis, ASM International, 2001; 10. Materials and Surface Engineering, Research and development, ed. J Paulo Davim, Elsevier, 2012
MSE676	MATERIALS FAILURE: ANALYSIS AND PREVENTION	3-0-0-0-9	1. Introduction to Failure analysis and prevention: Concepts, root causes analysis, primary root causes, design deficiencies, material defects, manufacturing/installation defects, categories of failure, failure prevention; 2. Failure Analysis: Processes, objectives, planning and preparation, practices and procedures; 3. Fracture modes, Ductile fracture of metallic. materials and their interpretations, factors affecting ductile brittle relationships; 4. Failure characteristics of Ceramics and Plastics; 5. Brittle fracture in normally ductile metallic alloy, microstructural aspects of brittle fracture; 6. Fatigue fracture, macroscopic and microscopic characteristics, statistical aspects of fatigue, Fatigue failure prediction and life assessment; 7. Wear Failures and Prevention; 8. Corrosion related failures, Stress corrosion cracking, Hydrogen damage and embrittlement, Biological corrosion failures; 9. Elevated temperature failures, creep and stress rupture, metallurgical instabilities; 10. Distortion failures and deformations; 11. Structural life assessment methods, Non-destructive techniques; 12. Tools and techniques in failure analysis: General Practices, Photography, X-rays, Metallographic techniques, Fractography; 13. Illustrative; Case studies of engineering failure due to improper processing practice, improper treatment procedure, improper design, unanticipated service conditions, improper material selection, improper service condition etc. Examples of component failures in (metals, ceramics and plastics. **Course References:** 1. Source book in failure analysis, American Society of Metals, Metals Park, Ohio, 1974; 2. Understanding how components fail, D.J Wulpi, ASM International, The Materials Information Society, 1999; 3. A.J. McEvily, Metal Failures: Mechanisms, Analysis, Prevention, Jolm Wiley and Sons,2002; 4. Practical engineering failure analysis, H.M. Tawancy, A. UlHamid and N.M. Abbas, Marcel Dekker, New York, 2004; 5. Failure analysis and prevention, Volume II, ASM Handbook, The Materials Information Society, 2002; 6. Failure analysis of engineering structures: Methodology and case Histories, V.Ramachandran, A.C. Raghuram, R.V. Krishnan and S.K. Bhaumik , ASM International,2005.

MSE680	GRAIN BOUNDARY ENGINEERING	3-0-0-0-9	Grain boundary structure: Geometrical aspects, Degress of freedom, Principles governing grain shape and size their orientation. Theoretical formulations: Structural unit model, Plane matching model, O Lattice model, Special boundaries, CSL and DSC Lattice. Boundary energy and equilibria, Grain Boundary types, GB mobility and boundary solute interactions. GB structure and Properties: mechanical strength wear, creep magnetic, electrical etc. Simulation and modelling. Grain boundary engineering strategy: Deformation, thermomechanical treatment trace additions, Magnetic Field etc. GB descriptors: Connectivity, density junction distribution, Character distribution. Boundary Characterization Tools: Xray, EBSDOIM, CTEM, AEM, HRTEM, etc. Macrotexture analysis: Pole figure measurement, Xray diffraction, neutron diffraction methods. Micro texture analysis: Automated EBSD Kikuchi pattern, Hough's transform, SEMOIM based TEM based, Schemes for representation of Data Prospective applications: Superplasticity. Creep resistance, Corrosion Resistance, Superconductivity, Electronic ceramics etc.
MSE681	SOLAR ENERGY TECHNOLOGIES AND MATERIALS	3-0-0-0-9	1. Introduction to the course. 2. Solar Spectrum. 3. Available solar energy technologies. 4. Solar Thermal Energy Conversion: a. Fundamentals, b. Materials and Technologies, c. Applications, d. Present status. 5. Photovoltaic Devices and their fundamentals, 6. Solar Electricity Conversion or Solar Photovoltaics. a. Technologies, b. Materials, devices and issues, first generation technologies Si based. Second generation technologies (low cost) thin-films (aSi, CdTe, CIGS); solar concentrators. Third generation (high efficiency and low cost) Organic solar cells, multijunction, quantum dot solar cell. Device Characterizationd. Comparative Performance7. PV Processing with emphasis on migration from solar cells to modules to systems. Present status and Future outlook **Course References:** 1. Thin Films Solar Cells, K.L. Chopra, McGraw Hill; 2. Physics and Technology of Solar Energy, H. P. Garg, M. Dayal, G. Furlan (1987) a. Volume 1: Solar Thermal Applications, b. Volume II: Photovoltaic and Solar Energy Materials); 3. The Physics of Solar Cells (Properties of Semiconductor Materials), Jenny Nelson; 4. Third Generation Photovoltaics: Advanced Solar Energy Conversion (Springer Series in Photonics) by M.A. Green; 5. Flexible Solar Cells by Mario Pagliaro, Giovanni Palmisano, and Rosaria Cirirninna (HardoverDec 10, 2008); 6. Physics of Solar Cells: From Basic Principles to Advanced Concepts (Physics Textbook) by Peter Warfel (Paperback April 13, 2009).
MSE682	COMPUTER SIMULATIONS IN MATERIALS SCIENCE	3-0-0-0-9	Objective of the course is to introduce students to the field of computational materials science. The course commences with a brief discussion of basic physics and numerical methods, essential for the rest of the course. The topics are divided into two major categories, classical and quantum mechanical simulation techniques. The first part focuses primarily on two popularly used methods, molecular dynamics

			and Monte Carlo; discussing basic theory, applications and examples related to materials science. The second part focuses on density functional based tight binding (DFTB) method. Basic applications, such as simple band structure calculation and geometry optimization and advanced topics such as electron transport calculations will be discussed. **Course References:** 1. Molecular dynamics simulation: Elementary methods, J. M. Haile (Wiley Professional); 2. The art of molecular dynamics simulation, D. C. Rapaport (Cambridge University Press); 3. Computer simulation of liquids, Allen and Tildesley (Oxford); 4. Computational materials science: an introduction, June Gunn Lee (CRC Press); 5. Electronic structure: basic theory and practical methods, Richard Martin (Cambridge).
MSE683	CRYSTALLOGRAPHIC TEXTURE & MECROSTRUCTURAL ENGINEERING	3-0-0-0-9	Introduction to crystallographic texture. Refresher on Xray diffraction: basic diffraction concepts, reciprocal space, instrumentation and geometry. Basics of neutron and synchrotron diffraction and comparison. Texture data representation: pole figures, inverse pole figures, orientation distribution function. Measurement of pole figures: experimental details, data processing, indexing Determination of Orientation Distribution Function and Misorientation. Distribution Function: calculation techniques, different notations, 3D and 2D representation. Introduction to Electron Back Scatter Diffraction and microtexture: instrumentation, sample preparation, data acquisition and analysis. Mechanisms of evolution of texture during processing: solidification, phase transformation, deformation, annealing. Modelling texture evolution. Texture evolution and measurement in thin films. Grain boundary engineering: Principle, practice and applications. Material formability and texture. Functional properties and texture. **Course References:** 1. An Introduction to Texture in Metals; M. Heatherly, W. B. Hutchinson, Monograph no. 5, The Institution of Metallurgist London 1979; 2. Introduction to Texture Analysis: Macrotexture, Microtexture, and Orientation Mapping;0. Engler, V. Randle, CRC Press, 2010; 3. Texture and Anisotropy: Preferred Orientations in Polycrystals and their Effect on Materials Properties; U. F. Kocks, C. N. Tome, H.R. Wenk, Cambridge University Press, 2000; 4. Research publications on: Texture manipulation and control; Microstructural engineering; and Grain boundary engineering.
MSE684	ADVANCED MICROELECTRONICS PACKAGING	3-0-0-0-9	Microelectronics Packaging Architectures. History of microelectronics packaging Moore’s law for packaging, 2.5D and 3D packaging technologies. Design Aspects of Packaging. Electrical design for signal, power, and electromagnetic interference Heat transfer in packaging. Warpage management through design and materials

			Wafer Level Processes and Materials. Die backside metallization. Die prep processes and adhesive tape and wafer coat materials. Substrate Level Processes and Materials Basics of ceramics, glass, organic, and silicon package substrates. Passive components Chip-to-package interconnections and assembly. Underfill and mold materials chemistry and process. Surface Mount Technology (SMT). Solder materials including Sn-Pb, SAC, SnBi, and high-reliability solders. PCB design and SMT process optimization. Reliability Challenges. Thermomechanical and drop-shock reliability Current stressing and electromigration driven failures. Relevance of Different Characterization Techniques in Packaging. Microscopy, Surface characterization, physical properties measurements techniques. Specialized Applications of Packaging Packaging technologies for applications in automotive, bioelectronics, flexible electronics, smartphones, etc. Overview of Recent Advancements in Packaging Through the Latest Literature. **Course references:** 1. Tummala, R.R., 2019. Fundamentals of Device and Systems Packaging: Technologies and Applications. McGraw-Hill Education; 2. Greig, W., 2007. Integrated circuit packaging, assembly and interconnections. Springer Science & Business Media; 3. Morris, J.E., 2018. Nanopackaging. Springer, Cham; 4. Bath, J. ed., 2020. Lead-free Soldering Process Development and Reliability. John Wiley & Sons. 5. Suhir, E., Lee, Y.C. and Wong, C.P. eds., 2007. Micro-and opto-electronic materials and structures: physics, mechanics, design, reliability, packaging.
MSE685	THIN FILM PHYSICS & APPLICATIONS	3-0-0-0-9	Surface science; experimental techniques to study surfaces; kinetics of surface processes impingement of atoms, scattering, adsorption, sticking coefficient; Film nucleation and growth mechanisms, critical radius of nuclei, computer simulation of film growth, microstructure evolution; Film growth by evaporation, sputtering, chemical vapour deposition, atomic layer epitaxy, liquid phase epitaxy, solgel technique etc, Electrical, optical, magnetic and mechanical properties of thin films and their applications.
MSE686	SEMICONDUCTOR DEVICES AND PROCESSING	3-0-0-0-9	Review of semiconductor physics, carrier statistics, generation recombination and carrier transport. Devices: PN junctions, Schottky barrier diodes, MOS capacitors, field effect transistors. Planar technology and process flows for PN junctions and Schottky diodes. Oxidation, diffusion (oxidation enhanced diffusion, transient enhanced diffusion), ion implantation, deposition (chemical and physical vapour techniques), etching; Lithography; Device and process integration, with MOSFET as an example. **Course References:** 1. Nanomaterials, Nanotechnologies and Design: An Introduction to Engineers and Architects, D. Michael Ashby, Paulo Ferreira. Daniel L. Schodek, Butterworth Heinemann, 2009; 2. Handbook of Nanophase and Nanostructured Materials (in jour

			volume.). Ed: Z.L. Wang, Y. Liu, Z. Zhang, Kluwer Academic/Plenum Publishers, 2003; 3. Encyclopedia of Nanoscience and Nanotechnology, Ed.: Hari Singh Nalwa, American Scientific Publishers, 2004; 4. Handbook of Nanoceramics and their Based Nanodevices (Vol. 2) Edited by T eungYuenTyeng and Hari Singh NahFa, American Scientific Publishers.
MSE688	NANOMATERIALS: PROCESSING AND PROPERTIES	3-0-0-0-9	Definition and Classification of Nanomaterials, Fundamental Properties of various primary material classes (Metals, ceramics and Polymers), Size dependent properties and various characterization techniques of Nanomaterials, Synthesis/ Consolidation routes to produce Nanomaterials, Mechanochemical synthesis to produce nanosized precursor powders, Various routes to produce Nanometallic alloys (Rapid solidification), Challenges in processing bulk ceramic nanomaterials; Various densification routes for nanoceramics and nanoceramic composites, Processing structure properties of important bulk nanomaterials, Mechanical Properties, Thermal properties, Tribological Properties, Biological Properties(Biomedical applications), Applications of bulk nanomaterials, Critical issues related to understanding properties of nanomaterials.
MSE689	MULTI FUNCTIONAL OXIDES: THIN FILMS & DEVICE	3-0-0-0-9	Fundamentals of oxides: crystal structure, defect chemistry, and properties; focus on various material systems, methods of fabrication e.g. solid-state chemistry. Oxide thin films. polycrystalline versus epitaxial, main film deposition techniques: physical vapor and chemical deposition methods, PVD techniques: sputtering (fundamentals of glow discharge processes and film deposition RF and DC magnetron sputtering new approaches), laser ablation (basic science, applications, various approaches), science and technology of evaporation and molecular beam epitaxy (MBE) Chemical processes basic and technological issues of sol-gel chemical vapor deposition atomic layer deposition; PVD vis-à-vis chemical processes; issues related to epitaxy and case studies. Characterization methods: Structural techniques uses of X ray diffraction, atomic force microscopy scanning and transmission electron microscopy, spectroscopic methods; Electrical Measurements. Devices types of devices, fabrication: fundamentals and issues; Lithographic methods: conventional and next generation, FIB (field ion) techniques, Nanofabrication: principles, processes and issues, Use of Scanning force microscopy in nanofabrication case studies.
MSE693	MATERIALS SCIENCE TECHNOLOGIES FOR APPLICATIONS IN LIFE SCIENCES	3-0-0-0-9	Introduction to integrating nanotechnology and materials science with life sciences: Introduction to various size regimes in life science and materials science Importance of integration of materials science and engineering with life sciences. Proteins and DNA: Structure and properties : Cells organelles and building blocks of important molecules in cell (1) Protein structure, organization, functions with emphasis on antibodies and enzymes, regulation of enzyme activity, protein phosphorylation DNA: structure and function of DNA, DNA replication

			and repair Microfabrication techniques and soft lithography; Fundamentals of bioMEMS, microfluidic devices and Lab on chip devices Materials for MEMS Photolithography: (single crystal silicon, mask, oxide formation, resist application, baking, exposure, positive and negative resist, developing, etching. Etching: Dry Vs wet and isotropic Vs anisotropic, plasma (DC arc and RF), DRIE, wet bulk surface micromachining, 3D structure with sacrificial layer, LIGA Deposition: physical and chemical vapour deposition Soft fabrication: application of polymers in bioMEMS, microcontact printing, microtransfer molding, micromolding in capillaries, injection molding, hot embossing Biocompatibility : Definition of biocompatibility, host response to implanted device, in vivo and in vitro tests for biocompatibility Overview of immune system (innntate and adaptive immunity, cell mediated and humoral immunity), B cells, T cells, MHC **Course References:** 1. B. Alberts eta/., Essential Cell Biology. (Garland Publishing Inc., New York, ed. Third, 2009); 2. S. S. Saliterman, Fundamentals of bioMEMS and medical microdevices. (Wiley lnterscience, Bellingham, 2005); 3. T.J. Kindt et. al., Kyby immunology. (W.H. Freeman, 6^{th} edition 2007); 4. C. S. S. R. Kumar, Biofunctionalization of Nanomaterials. C. S. S. R. Kumar, Ed., Nanotechnologies for the life sciences (WileyVCH, Weinheim, 2006), vol. 1, pp. 366; 5. C. S. S. R. Kumar, Nanomaterials for biosensors. C. S. S. R. Kumar, Ed., Nanotechnologies for thelife sciences (WileyVCH, Weinheim, 2006), vol. 8; 6. C. S. S. R. Kumar, Nanosystem characterization tools in the life sciences. C. S. S. R. kumar, Ed., Nanotechnologies for the life sciences (WileyVCH, Weinheim, 2005), vol. 3.7. J. M. Anderson, Annu Rev of Matl Res, 31, 81 (2001)
MSE694	NANOSTRUCTURES AND NANOMATERIALS: CHARACTERIZATION AND PROPERTIES	3-0-0-0-9	Overview of Nanostructures and Nanomaterials: classification (Dimensionality, Morphology/ shape/structure of nano entities, New Effect/ Phenomena). Crystalline nanomaterials and defects therein. Hybrid nanomaterials. Effect of size, structure, mechanism, and property on material performance. Multiscale hierarchical structures built out of nanosized building blocks (nano to macro). Euclidian, Hyperbolic and Spherical space structures. Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires, Graphene, Quantum Dots. Thermodynamics of Nanomaterials. Configurational entropy and Gibbs free energy of nanocrystals. Wulff reconstruction. Surface reconstruction and reconfiguration. Adsorption and Absorption. **Course References:** 1.Nanomaterials, Nanotechnologies and Design: an Introduction to Engineers and Architects, D.Michael Ashby, Paulo Ferreira, Daniel L. Schodek, Butterworth Heinemann, 2009; 2. Handbook of Nanophase and Nanostructured Materials (in four volumes), Eds: Z.L. Wang, Y. Liu, Z.Zhang, Kluwer Academic/Plenum Publishers, 2003; 3. Encyclopedia of Nanoscience and Nanotechnology, Ed.: Hari Singh Nalwa, American Scientific Publishers, 2004; 4. Handbook of Nanoceramics and their Based Nanodevices (Vol. 2) Edited by TseungYuen Tseng andHari Singh Nalwa, American Scientific

			Publishers; 5. Introduction to Nanoscience, G.L. Hornyak, J. Dutta, H. F. Tibbals, A.K. Rao, CRC Press (2008).
MSE695	DIFFRACTION AND SPECTROSCOPY TECHNIQUES FOR SURFACE CHARACTERISATION	3-0-0-0-9	Diffraction and Spectroscopy Techniques for Surface Course Details: Importance of Surface Characterization. Present status sensitivity and resolution achievable. Diffraction Techniques: basic diffraction theory; Various Small Angle Xray Scattering techniques, and its applications; electron diffraction, LEED and RHEED. Properties of neutron radiation: neutron sources: Small angle neutron scattering; illustrative analysis using diffraction techniques Spectroscopy: Basic principles of Spectroscopy. Principles of XPS, Instrumentation, XPS patterns, Quantitative analysis. Chemical effect, Chemical shell XPS imaging; Auger electron generation: Principle of AES. Chemical effect, Quantitative analysis, Depth profiling, Applications; Static and Dynamic SlMS, Common modes of analysis, quantitative and Qualitative analysis; Case studies on the spectroscopic analysis of surfaces. **Course References:** l. Encyclopaedia of Material's Characterisation, C. R. Brunelle. C. A. Evans and S. Vilson, Butterworth Hennmann, 1992. Boston; 2. Characterisation of Materials Volume 2. Editor: E.N. Kaufmann, Wiley lnterscience. 2003.New Jersey; 3. Surface Anctvsis kfethods in; Material's Science. D. J. oconnors, B.A. Sexton. and R. St. Smart, Springer (2003); 4. Materials Charocterization. published in 1986 as Volume l0 of the 10th Edition Metals Handbook, ASM International. 1986 (Fifth printing 1998).
MSE888	Introduction to Professional and Communication Skills	2-0-0-2-8	(Part A) Materials Research as Profession: Materials as backbone of various engineering disciplines, interdisciplinary nature of research in materials, broad research areas in the department, new trends in research and career choices. Professional Ethics: Workplace ethics and best practices; sharing workplace; sharing information; use of centralized facilities; Societal impact (energy/environment). Safety: ergonomics, personal, equipment, chemical, electrical, fire-hazards etc.; data-safety and backups. Publishing and Patenting: Dissemination of research outcome as publication, patent, and/or conference presentations; Identifying appropriate journals, conferences; various stages of publication and patenting; Scientometrics. (Part B) Technical and Scientific Communication: Importance of communication in scientific and technical research; various modes of communication. Scientific Literature: Searching and managing scientific literature; databases. Key journals in different domains of materials research. Literature Review: Reading and understanding scientific literature; questioning hypothesis, method, data, and analysis presented in literature; taking and managing notes on literature review. Critical analysis of scientific results: Visualization of scientific results: graphing/plotting with trend lines, normalization, error bars, significance, comparison, etc. of numerical data; Technical figures: optical and electron micrographs, XRD, spectroscopic data analysis:

			baseline correction and peak fittings. Scientific and Technical writing: Technical reports; brief report on research outcomes; manuscript preparation, thesis, and proposal writing; Plagiarism and paraphrasing, ethical use of software for paraphrasing; Managing references and citations; journal styles (language, tense, etc.); Software for grammar check and correction (Grammarly); Graphical abstracts; cover letter for manuscript submission and replying to queries of editor/reviewers. Scientific presentations: Abstract for a conference, preparing content and slides for presentation, knowing the intended audience, time management, Q&A and discussion; 2-3 min video/live presentation; SOTA, Open-Seminar, and thesis defence. Teaching/Job presentations: Preparing for a career in academia/industry job interview/presentations; teaching seminar: choice of topic, level of instruction, and answering questions. Professional Communication: Resume/CV, cover letter, official communication, email communication, SOP/Research Statement/Teaching Statement etc.
MSE801	SEMINAR PARTICIPATION	0-0-0-0	Seminar Participation
MSE699	M.TECH. THESIS	0-0-0-0	M. Tech. Thesis
MSE699	M. TECH. THESIS (FOR DUAL DEGREE ONLY)	0-0-0-0	M. Tech. Thesis
MSE799	Ph.D. THESIS	0-0-0-0	Ph. D. Thesis