2^{nd} Year Syllabus

3rd Semester

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (3rd Semester)	**Electronic, Magnetic and Di-electric Materials**	MMT 201	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Evaluate the nature of electrical conduction in metals and semiconductors.
CO2	Analyze the modern techniques for fabrication / synthesis of semiconductor materials.
CO3	Analyze important semiconductor devices such as metal oxide semiconductors, PN junctions, transistors like BJT's and FET'S.
CO4	Evaluate the magnetic properties of materials and categorize latest dielectric materials and their applications and discover the latest developments/trends of electronic, magnetic and dielectric materials in various fields.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Free electron theory and its limitations, Metallic conduction and factors affecting conductivity, Semiconductor materials, p and n- type semiconductors and techniques of processing semiconductors. Single crystal growth, oxidation, diffusion, ion and electron beam, ion implantation, plasma technology etc. MOS, MNOS and SOS, etc. technologies, I.C. technologies etc., Doping, p-n junctions, etc.	**20**
Module 2	Magnetic materials; dia, para, ferro, ferri, anti-ferro, ceramic magnetic materials. Hall effect, Magnetism, theory of magnetism, Hard and soft Magnetic materials, their classification and applications, technology of their production.	**10**
Module 3	Di-electric materials, Piezo-electric and ferro-electric materials, dielectric breakdowns, ferrites, optical materials, lasers etc. Performance of materials in the development and growth of: Electrical, electronics and telecommunication equipment/ system, Energy sector, and Bio-Medical.	**12**
	Total Hours	**42**

Books Recommended:

1. Introduction to Solid State Physics, Kittel, Wiley, 2004.
2. Physical Metallurgy Principles, Reed Hill, Affiliated East West Press Pvt Ltd. 2006.
3. Principles of Electronic Materials and Devices, SO Kasap, McGrawHill, 2007.
4. Materials Science & Engineering, Callister, Wiley, 2008.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (3rd Semester)	**Thermodynamics of Materials**	MMT 202	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply the laws of thermodynamics to both open and closed material systems, analyzing the spontaneity of chemical reactions and utilizing concepts like enthalpy and heat capacity to assess energy changes within systems.
CO2	Analyze changes in entropy within a system and their relationship to the second law of thermodynamics, assessing changes affect the overall behavior and direction of thermodynamic processes.
CO3	Analyze solution thermodynamics behavior and Le Chatelier's Principle, while evaluating fugacity, activity, and equilibrium constants in relation to the third law.
CO4	Evaluate the principles of electrolysis and their role in determining thermodynamic quantities using electrochemical cells.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction:** Basic concepts, postulates, and basic problems of thermodynamics, Reversible and irreversible reactions. First law of thermodynamics: Enthalpy, Heat capacity.	**8**
Module 2	**Thermochemistry:** Hess's law. Flame temperature, Second law of Thermodynamics, Entropy and its change, Free energy and Gibb's Helmholtz equation, Third law of Thermodynamics, Fugacity, activity and equilibrium constant, Free energy calculations, Activity measurement, Ellingham diagram	**10**
Module 3	**Behaviour of Solutions:** Introduction to statistical thermodynamics, Le Chatelier's Principle,Partial Molal Quantities, Gibbs-Duhem Equation, Solution Classification: Ideal, Non-Ideal, and Dilute, Raoult's and Henry's Laws, Standard and Alternative States, Sievert's Law and Applications, Excess Functions in Solution Mixing	**12**
Module 4	**Regular solutions:** Clausius-Clapeyron Equation, Phase Equilibrium, Principles Equilibrium Dynamics: Liquid-Vapor, Solid-Liquid, and Solid-Vapor Trouton's Rule and its Applications	**6**
Module 5	**Electrochemistry in thermodynamics:** Fundamentals of Electrochemical Cells Eh-pH diagram, Principles of Electrolysis, Determination of Thermodynamic Quantities via Electrochemical Cells	**6**
	Total Hours	**42**

Books Recommended:

1. Metallurgical Thermodynamics, Kinetics and Numericals, S.K. Dutta, A.B. Lele, S.Chand, 2011
2. Problems in Metallurgical Thermodynamics & Kinetics, G.S Upadhyay& R.K Dube, Pergamon Press, 1985
3. Introduction to the Thermodynamics of Materials, Sixth Edition [6th ed.], David R. Gaskell, David E. Laughlin, CRC Press, 2018

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (3rd Semester)	**Physical Metallurgy**	MMT 203	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify the various aspects of crystallography to determine the crystal structure of materials.
CO2	Analyze the microstructure and its influence on the properties of ferrous and non-ferrous alloys.
CO3	Evaluate the phase diagram to understand the relationship between phases in equilibrium and suggest thermal treatments to predict the phase formation and use in the development of materials.
CO4	Explain the influence of temperature and composition on the mechanism of the solidification process in metals and alloys.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Structure of metals**: Crystal structure, systems and Bravais lattices, symmetry elements; Indexing of crystallographic planes and directions; Coordination number and effective number of atoms for common crystalline structure, atomic packing factor and theoretical density, linear and planar densities; stereographic projections, interplanar spacing and angles, zone axis; concept of texture.	**10**
Module 2	**Microstructure & Crystal Imperfections**: Point defects; dislocations, burgers vector and its representation, dislocation in FCC metals- Shockley partials, stacking faults; Grain boundaries- small and high angle boundaries, tilt and twist boundaries, twin boundaries; methods of grain size determination; defects and their influence on the properties of materials (strain hardening), effect of temperature on defects- recovery, recrystallization and grain growth microstructure.	**10**
Module 3	**Principles of Alloy formation:** Solid solutions and their types, primary and intermediate phase formation, Hume-Rothery rules, electron compounds, intermetallic compounds.	**3**
Module 4	**Phase diagrams**: Phase stability and free energy of mixing; free energy-composition diagrams and temperature-composition phase diagrams. Phase rule & lever rule Equilibrium phase diagrams of various binary alloys involving- isomorphous, eutectic, eutectoid, peritectic, peritectoid, monotectic, and precipitation reactions; Iron carbon equilibrium diagram and the critical phenomenon; Ternary phase diagram-Gibbs triangle.	**10**
Module 5	**Solidification of metals and alloys:** Concept of free energy, entropy, surface energy, under cooling and cooling curves; Nucleation & Growth - homogeneous & heterogeneous nucleation, growth of solid- smooth, stable interface growth; Temperature inversion in pure metals; dendritic growth in pure metals, alloy solidification, constitutional supercooling, freezing of ingots.	**9**
	Total Hours	**42**

Books Recommended:

1. Introduction to Physical Metallurgy, S. Avner, Tata Mc Graw Hill, 2008
2. Principles of Physical Metallurgy, Reed Hill, CT: Cengage Learning, 2008
3. Physical Metallurgy- Principles and Practice, V.Raghavan, Prentice Hall of India, 2007
4. Material Science and Engineering, W D Callister, John Wiley and Sons, 2000
5. Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2017
6. Engineering Physical Metallurgy, Y. Lakhtin, MIR Publishers, 1998
7. Materials Science and Engineering, V.Raghavan, Prentice Hall of India, 2015
8. Physical Metallurgy, Hansen Peter, Cambridge University Press, 1987
9. Physical Chemistry of Metals, Darken & Gurry, CBS, 2002
10. Physical Metallurgy Principles and Design, Gregory N. Haidemenopoulos, Taylor & Francis Group, 201
11.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (3rd Semester)	**Mineral Dressing and Principles of Extractive Metallurgy**	MMT 204	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply the law of comminution to correlate the energy consumption and particle size reduction
CO2	Categorize the mineral processing operation and extractive metallurgical processes.
CO3	Analyze the different mineral beneficiation processes and extractive metallurgical processes.
CO4	Apply the principles of extractive metallurgy towards production of different ferrous and non-ferrous metals

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Mineralogy, Comminution, Screening, Sizing, and Classification:** Differentiate between mineralogy and extraction metallurgy, important of mineral processing and extraction metallurgy, Studies of important metallic and non-metallic minerals and their origin and applications, sources of minerals, sampling methodology and equipment, Gy's equations, different type of crushers and grinding mills, Laws of Comminution, interlocking and liberation of materials, standard screening tests, sorting, sizing, and classification, theory and practice of sedimentation and filtration.	**12**
Module 2	**Gravity Concentration Techniques, Froth Flotation, and Electrostatic and Magnetic Separation:** Principles of Jigging, Tabling, Heavy media separation, Natural and Artificial Floatability of minerals, frothers, collectors, depressants, activators/deactivators, PH modifiers, etc. flotation machine, conditioning in flotation, multistage flotation, and column flotation, principles of electrostatic and Magnetic separation (Dry and Wet type)	**10**
Module 3	**Pyrometallurgical and Hydrometallurgical processes:** Drying, and calcination roasting, relevance of Ellingham diagram in metal extraction, reduction of metal oxide, matte smelting and converting, metal refining processes: fire-refining, liquation and distillation, leaching and its methods, construction & use of Pourbaix diagram, bioleaching, solution purification, and concentration: solvent extraction, and ion exchange, recovery of metals from leach solution.	**10**
Module 4	**Electrometallurgical Processes and Process Flow Sheets:** Principles of electrolysis, electrolytic systems, electro-refining, electrowinning and other electro-metallurgical processes, production of iron and steel, aluminium, copper, magnesium, zinc and lead with process flow sheets.	**10**
	Total Hours	**42**

Books Recommended:

1. Gaudin A.M., Principles of Mineral Dressing, McGraw Hill Boo, TMH Edition, 1971.
2. Taggart A.F., Elements of Ore Dressing, J. Wiley & Sons, 1951, London/NY.
3. Taggart, Handbook of Mineral Dressing, Wiley Handbook,
4. Wills B.A., Mineral Processing Technology, Elsevier, 7th edition, 2014.
5. Newton J., Extractive Metallurgy, Wiley.
6. Dennis W. H., Extractive Metallurgy – Principles, and Applications, Pitman.
7. Ray H.S., Ghosh A., Principles of Extractive Metallurgy, New Age International Publishers.
8. Ray H.S., Sridhar R., and Abraham K.P., Extraction of Non-Ferrous Metals, Affiliated East West.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (3rd Semester)	**Probability & Statistics**	MAT 206	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: A student should have basic knowledge of set theory.

Course Outcomes: At the end of the course, a student will be able to:

CO No.	Course Outcomes
CO1	Analyse various concepts of statistics and apply to various engineering problems
CO2	Evaluate various engineering problems using concepts of probability
CO3	Solve various engineering problems related to discrete and continuous distributions
CO4	Analyse sampling theory and apply it to various engineering problems

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Introduction to basic Statistics, moments, correlation, regression, methods of least square, curve fitting (polynomials, exponentials).	**10**
Module 2	Basic definitions of probability, conditional probability with standard results, Bayes theorem with examples. Discrete and Continuous Random variables, Distribution functions, Expectation and Variance of Probability distribution, and Moment Generating function, Moments and properties.	**12**
Module 3	Discrete distributions: Binomial, Poisson and Geometric distributions and their applications.Continuous distribution: Uniform, Exponential and Normal distributions, Normal approximation to Binomial distribution and their applications.	**10**
Module 4	Introduction to sampling theory, types of sampling, purposive sampling, random sampling, simple sampling, stratified sampling, test of significance, null and alternate hypothesis, errors in sampling.	**10**
	Total Hours	**42**

Books Recommended:

1. S. Ross, *A First Course in Probability*, 6th Edition, Pearson Education India, (2002).
2. S. C. Gupta and V. K. Kapoor, *Fundamentals of Mathematical Statistics*, 12th Edition, Sultan Chand & Sons Publications, (2020).

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (3rd Semester)	**Entrepreneurship Development**	HST 006	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

COURSE OUTCOMES:
After completing this course, the student must demonstrate the knowledge and ability to:

CO1	Apply the concepts of entrepreneurship and innovation.
CO2	Analyze entrepreneurship considering various theories and models.
CO3	Appraise Training Programme to inculcate Entrepreneurial acumen.
CO4	Develop Entrepreneurship Development Skills.

Detailed Syllabus:

Module No.	Contents	Hours
Module-1	Entrepreneurship: Importance and growth, Characteristics of entrepreneurs, Ethical and social responsibilities of entrepreneurs, Challenges and opportunities of different forms of entrepreneurship, Entrepreneurial motivation.	**10**
Module-2	Theories of entrepreneurship, Schumpeter's Theory of Innovation, Economic Theory of Entrepreneurship, Resource based, Opportunity based, psychological and Sociological theories of entrepreneurship.	**11**
Module-3	Designing Appropriate Training Programme to inculcate Entrepreneurial Spirit, Training for New and Existing Entrepreneurs, Feedback and Performance of Trainees, Training entrepreneurs for creative problem solving.	**10**
Module-4	Entrepreneurship Development Skills: Meaning of Entrepreneurship skill, Types of Entrepreneurship Skills: Business management skills, Teamwork and leadership skills, Time management and organizational skills	**11**
	Total Hours	**42**

Books Recommended:

1. Kumar, A. (2012). *Entrepreneurship: Creating and Leading an Entrepreneurial Organization.* Pearson Education India
2. Rao, T., & Kuratko, D. (2012). *Entrepreneurship.* Cengage learning India.
3. Ramachandran, K. (2012). *Entrepreneurship Development*. McGraw Hill Education India.
4. Roy, R. (2020). *Entrepreneurship (Ed. 3rd).* Oxford University Press India.
5. Chole, R. R., Kapse, P. S., & Deshmukh, P. R. (2012*). Entrepreneurship Development and Communication Skills.* Scientific Publisher.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (3rd Semester)	**Laboratory Practice in Physical Metallurgy**	MML 205	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60 Marks		40 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identification of crystal structures using models
CO2	Describe the primary components of a Metallurgical Optical Microscope.
CO3	Illustrate the metallographic sample preparation of ferrous and non-ferrous specimens and examine the microstructure under optical microscope.
CO4	Analyze the grain size and phase fraction by using standard measurement methods.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	1. To study the crystal structure (SC, BCC, FCC and HCP) using a hard sphere model. 2. To study the various components of a metallurgical microscope. 3. To prepare the metallic sample for metallographic examination.	**6**
Module 2	4. To determine the grain size and phase fraction of a given metallic sample by quantitative Metallography. 5. To study the microstructure of various steel samples. 6. To study the microstructure of various cast iron samples.	**8**
Module 3	7. To study the microstructure of various copper base alloys. 8. To study the microstructure of aluminium and its alloys. 9. To study the microstructure of Pb and Sn alloys.	**8**
Module 4	10. Stereographic projections - construction of Wulff net. 11. Plotting of Binary and ternary phase diagrams using thermocalc software package.	**6**
	Total Hours	**28**

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (3rd Semester)	**Laboratory Practice in Mineral Dressing & Principles of Extractive Metallurgy**	MML 206	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60 Marks		40 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply the concept beneficiation technique to increase concentration of different minerals.
CO2	Analyze the effect of grinding time and grinding media on the Ore particle size.
CO3	Evaluate the reduction ratio, capacity of Blake Jaw Crusher and Roll crusher, and verification of law of comminution.
CO4	Testing the efficiency of different beneficiation techniques (Ore separation techniques) and effect on the concentration of Ore.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	1. To determine, and analyze the size distribution of a fixed granular solid by using a Test Sieve Stack. 2. To determine and analyze the size distribution of a fixed granular solid by using a Vibratory Sieve Shaker. 3. To perform Sieve analysis on a given dry milled Ore for ½, 1, and 2 hours and to calculate (i) Percentage loss in screening, (ii) the average size of particles and (iii) Plot various sizing curves.	**8**
Module 2	**1.** To study the parts of a Jaw Crusher (Blake Jaw Crusher) and to operate it using different ore materials and various gape settings, and determine the reduction ratios. **2.** To crush the Ore (Iron ore pellets) in a Primary Jaw Crusher (Blake Jaw Crusher), and to determine the average product size by sieving. **3.** To crush the Ore in the Roll Crusher, and determination of average product size using a sieve shaker.	**6**
Module 3	**1.** To study the effect of grinding time and weight of grinding medium on particles in Ball mill. **2.** To separate a mixture of two minerals of different densities by gravity concentration using the Wilfley Table, and determine the efficiency of the Tabling process. **3.** Beneficiation of Ore pulp mix using Froth Floatation Cell.	**8**
Module 4	**1.** To study about the magnetic separator, and the effect of magnetic field on the efficiency of the process (concentration of ore). **2.** Conduct the classification of a mill product using (i) Spiral Classifier and (ii) A Cyclone. **3.** Palletisation of iron ore fines.	**6**
	Total Hours	**28**

4^{th} Semester

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (4th Semester)	**Phase transformation and Heat Treatment of Metals**	MMT 250	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Explain the mechanism of phase transformations from the perspective of thermodynamics and kinetics of materials.
CO2	Analyze the mechanism of solid-state phase transformations.
CO3	Recommend the heat treatment processes to achieve the application-dependent properties.
CO4	Propose the heat treatment processes applicable to ferrous and non-ferrous alloys.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Fundamentals of Phase Transformations:** Classifications, Thermodynamics of Phase transformation, phase stability criteria; Diffusion in solid state and mechanism, Laws of diffusion, application of Steady-state and Non-steady State Diffusion, Kirkendal effect, Factors governing diffusion; Crystal Interfaces, Interfacial energy, solid/vapour interfaces, boundaries in single phase solids, interphase interfaces in solids, and interface migration.	**10**
Module 2	**Solid state transformations:** Theory of nucleation and growth kinetics, Overall transformation kinetics JMAK equations ; Isothermal transformation of Fe-C system, TTT diagrams of eutectoid, hypo-eutectoid and hyper-eutectoid steels; continuous cooling transformations (CCT); Eutectoid transformations, pearlite and bainite transformation; precipitation in age hardening alloys; Order-disorder transformation, massive transformation, spinodal decomposition. Martensitic phase transformations, characteristics and nature, morphology, crystallography, theory of nucleation and growth, case study on martensitic transformation in steels, shape memory effect.	**14**
Module 3	**Heat Treatment of steels:** Introduction to heat treatment; Different types of heat treatment processes and their application - Annealing, Normalizing, Spheroidizing, Hardening, Tempering, Austempering and Martempering; Role of alloying elements and their effect on $Fe\text{-}Fe_3C$ system; Hardenability of steels, methods of determining hardenability, effect of alloying elements on hardenability, factors affecting hardenability; Quenching- mechanism of heat removal during quenching, types and characteristics of quenchants. Types of heat treatment furnaces and furnace atmospheres.	**8**
Module 4	**Surface hardening and Chemical heat treatment of steels:** Induction hardening, Flame hardening, laser hardening, Electron beam hardening, Carburizing, Nitriding, Cyaniding and Carbonitriding.	**6**
Module 5	**Case Studies:** Heat treatment case studies of some ferrous and non ferrous alloys.	**4**
	Total Hours	**42**

Books Recommended:

1. Phase transformations in metals and alloys, Porter & Easterling, Chapman and Hall, London, 2015
2. Solid State Phase Transformations, V. Raghavan, Prentice Hall of India (P) Ltd, 1992.
3. Phase transformations in materials, Sharma R.C., CBS Publishers and Pvt. Ltd 2002
4. Heat Treatment Principles and Techniques, Rajan T.V., Sharma, C.P, Sharma A., PHI Ltd, 2004
5. Heat Treatment of Metals, Vijendra Singh, Standard Publishers Distributors, 1998
6. Steel and its Heat Treatment, Karl-Erik Thelning, Butterworths London, 1984
7. Material Science and Engineering, W D Callister, John Wiley and Sons, 2000
8. Principles of Physical Metallurgy, Reed Hill, CT: Cengage Learning, 2008
9. Handbook of Heat Treatment of Steels, Prabhudev, K H., Tata-McGraw Hill Publishing Co.2000
10. Heat Treatment, Metals Handbook Vol.4, American Society for Metals, ASM Metals Parks, Ohio, USA, 2001

Year(Semester)	Course Title	Course Code	L- T- P-Credits
2^{nd} Year (4^{th} Semester)	**Kinetics of Metallurgical processes**	MMT 251	**2-1-0-3**
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: Nil

Course Outcomes: At the end of the course, the student will be able to

CO1	Analyze the basics of Kinetic rate equations of different Metallurgical Processes
CO2	Formulate and solve rate equations for various reactions
CO3	Apply the diffusion kinetic principles to various metallurgical processes
CO4	Apply rate theory to various processes of Metallurgical and Materials Engineering

Detailed syllabus

Module No.	Contents	Hours
Module 1	Thermodynamics vs Kinetics, Importance of metallurgical kinetics, Heterogeneous and homogeneous reactions, Characteristic features of rate processes, Activation energy, Rate of a thermally activated process. Arrhenius Law, Effect of activation energy on reaction rate, Empirical and Semi-Empirical Kinetic, General rate equation	**10**
Module 2	**Kinetic Approaches:** Metallurgical systems and approaches in Kinetic analysis, Factors determining rate, Approaches towards Rate Laws, Examples of Empirical and Semi-empirical Approaches, Johnson-Mehl equation and applications Kinetic model for nucleation and growth, Reduced time plots and their examples, Kinetic analysis of chemically controlled reactions, Reaction steps and rate-controlling step, Solid-fluid reactions, Kinetic law for topo chemical reactions, Diffusion through product layer, Jander's equation, Smelting Reduction processes, Homogeneous and Heterogeneous Nucleation rate, Examples, Non-isothermal Kinetics, Example-Decomposition of $CaCO_3$	**16**
Module 3	**Kinetics applied to mass transfer:** Solid State Diffusion - Fick's Law, Mechanism of diffusion, Uphill diffusion, Kirkendall effect, Steady and transient diffusion; Kinetics of heterogeneous metallurgical operations: viz Gas-solid, slag-metal, and other such systems.	**16**
	Total Hours	**42**

Books Recommended:

1. A Textbook of Metallurgical Kinetics, Ahindra Ghosh and Sudipto Ghosh, PHI Learning, 2014
2. Kinetics of Metallurgical Processes, Hem Shanker Ray, Saradindukumar Ray, Springer. 2017
3. Metallurgical Thermodynamics, Kinetics and Numericals, S.K. Dutta, A.B. Lele, S.Chand, 2011

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (4th Semester)	**Non-Ferrous Metal Extraction**	MMT 252	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply understanding of non-ferrous metal sources in India to pinpoint extraction opportunities and resources.
CO2	Apply extraction methods for magnesium, aluminium, and tin from oxide ores and copper, lead, zinc, and nickel from sulphide ores and evaluate the design and optimization of processes for extracting metals based on their properties and chemical reactions.
CO3	Evaluate extraction methods for metals from halides like titanium, rare earths, uranium, and thorium, considering their efficiency and environmental impact. Synthesize knowledge of extraction techniques to develop methods for extracting precious metals such as gold, silver, and platinum.
CO4	Integrate understanding of waste management, energy utilization, and environmental concerns to address issues in the non-ferrous metal industry

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Sources of non-ferrous metals:** Sources in land and sea, exploration methods, methods of beneficiation, nonferrous metals wealth in India, nonferrous metals in Indian history, uses of nonferrous metals.	**4**
Module 2	**Extraction of metals from oxide ores:** Basic approaches and special features of specific extraction processes, extraction of metals such as magnesium, aluminium, tin.	**8**
Module 3	**Extraction of metals from sulphide ores:** Pyro-metallurgy and Hydro-metallurgy of sulphides, Production of metals such as copper, lead, zinc, nickel, etc.	**11**
Module 4	**Extraction of metals from halides:** Production of halides and refining methods, Production of reactive metals. Methods of extraction of metals such as titanium, rare earths, uranium, thorium, plutonium, beryllium, zirconium, etc.	**11**
Module 5	**Production of precious metals:** Methods applied for gold, silver and platinum group of metals, Secondary metals and utilization of wastes, Energy and environmental issues in nonferrous metals extraction.	**8**
	Total Hours	**42**

Books Recommended:

1. Extraction of Non-ferrous Metals, H. S. Ray, R. Sridhar, K. P. Abraham.
2. K. Grjotheim and B.J. Welch: Aluminium Smelter Technology, Aluminium-Verlag.
3. A.K.Biswas and W.G. Davenport: Extractive Metallurgy of Copper, Pergamon.
4. S.W.K Morgaon: Zinc and its Alloy, Mac Donald and Evans.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (4th Semester)	**Joining of Materials**	MMT 253	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Course Outcomes:

CO1	Apply principles of physics of welding to solve engineering problems related to welding.
CO2	Interpret the effect of joining methods based on application, fabrication and service conditions.
CO3	Differentiate the defects in welded joints and develop remedial actions to prevent such defects.
CO4	Demonstrate the use of standards and codes to identify welding performance.

Module No.	Contents	Hours
Module 1	**Fundamentals of Welding :** Physics of Welding**,** Conventional and special/recent welding practices including submerged, Laser, Plasma, MIG, TIG, Electron beam welding, solid-state welding processes, Brazing and Soldering, mechanical joining, adhesive joining.	**8**
Module 2	**Thermal and mechanical effects of joining:** Isotherm and thermal cycle, fusion and solidification, heat affected zone, microstructure, fastening, riveting, clinching, distortion and residual stresses in different joints, gas pick up by welds and its influence.	**15**
Module 3	**Joining of ferrous and non ferrous metals:** Plain carbon structural steels, high strength low alloy steels, alloy steels, cast iron, stainless steels, aluminium alloys, copper alloys, titanium alloys, nickel alloys, characterization, defects and remedial measures **Joining of non metallic materials:** Structural polymers, structural ceramics, composites, defects and remedial measures **Joining of dissimilar materials:** Structural steel-stainless steel, aluminium-copper, metal-polymer, metal-ceramic, microstructure, defects and remedial measures.	**12**
Module 4	Inspection, mechanical testing, non-destructive testing, standards and codes for joint testing and qualification of joints.	**7**
	Total Hours	**42**

Recommended Books:

1. Modern Welding Technology, Howard B Cary,Helzar, Pearson PrenticeHall, 2005.
2. Manufacturing Engineering and Technology, S. Kalpakjian R.S.Steven, PrenticeHall, 2001.
3. Welding Engineering And Technology, R.S.Parmar, Khanna Publishers, 2002.
4. Welding Technology, Gower A. Kennedy, Macmillan Publishing Company, 1974.
5. Welding – Principles and Application, Larry Jeffus, Delmar Thomson Learning, 1999.
6. Principles Of Welding, R W Messler, John Wiley Sons, 1999.
7. ASM Handbook Volume 6: Welding, Brazing, and Soldering, Editor: D.L. Olson, T.A. Siewert, S. Liu, G.R. Edwards, ISBN: 978-0-87170-382-8.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (4th Semester)	**Numerical Methods**	MAT 216	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: A student should have basic knowledge of calculus.

Course Outcomes: At the end of the course, a student will be able to:

CO1	Determine the numerical solution of algebraic and transcendental equations.
CO2	Solve the problems related to inverse by various numerical methods.
CO3	Analyze how to approximate the functions using interpolating polynomials and finding intermediate values.
CO4	Apply numerical techniques for solving ordinary differential equations.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Floating-point form of numbers, Round-off, Algorithm, Stability, Programming errors, Errors of numerical results, Error propagation, Basic error principle, Loss of significant digits. Bolzano's bisection method, iteration method, Regula-Falsi method, Newton-Raphson method, numerical solution for system of equations. Gauss elimination method, Gauss-Jordan method, Computation of Inverse by Gauss's Method, LU decomposition, Gauss-Seidel iteration method, Jacobi method, The Eigenvalue problem	**15**
Module 2	Interpolation Forward, Backward and Shift operators, Central differences, their relations, Existence, Uniqueness of interpolating polynomials, error of interpolation - unequally spaced data; Lagrange's formula, Newton's divided difference formula. Equally spaced data : finite difference operators and their properties, Newton's forward and backward interpolation formulae, Gauss's forward and backward.	**15**
Module 3	Numerical differentiation using difference techniques, Trapezoidal, Simpson's 1/3 and Simpson's 3/8 rule, Truncation error, Romberg's method. Picard's method, Taylor series method, Euler and modified Euler method, Runge-Kutta method of 4th order.	**12**
	Total Hours	**42**

Recommended Books:

1. S.S. Sastry, *Introductory methods in Numerical Analysis*, 5th Edition, Prentice Hall India learning Pvt. Ltd., (2012).
2. Kendall E. Atkinson, Han, *Elementary Numerical Analysis*, 3rd Edition, Wiley India Pvt. Ltd., (2006).
3. J.B. Scarborough, *Mathematical Numerical Analysis*, 6th Edition, Oxford and IBH Publishers, (2020).

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2nd Year (4th Semester)	**Engineering Economics and Management**	HST 004	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

COURSE OUTCOMES:
After completing this course, the student must demonstrate the knowledge and ability to:

CO1	Apply the management concepts within the engineering domain.
CO2	Analyze the various functions of management
CO3	Appraise the importance of economics in engineering context
CO4	Discuss the operation of different forms of markets and their competitive strategies.

Detailed Syllabus:

Module No.	Contents	Hours
Module-1	**Basics of Management:** Definition, Functions, Process and Significance of Management; Evolution of management thought; Theories of Management	**10**
Module-2	**Functions of Management:** Planning; Organizing; Staffing; Directing and Controlling. Nature and Significance of functions of management	**10**
Module-3	**Basics of Economics and Consumer Behaviour:** Economics- Meaning, Divisions and Importance (Engineering Context); Demand- Concept and Law, Elasticity of demand-types, measurement, and importance.	**10**
Module-4	**Market and Economic Policies:** Markets- Features, type; Perfect Competition, Monopoly, Monopolistic Competition, Duopoly and Oligopoly; Introduction to concepts of inflation, GDP, fiscal policy and monetary policy.	**12**
	Total Hours	**42**

Recommended Books:

1. Ahuja, H. L. (2016). Advanced Economic Theory: Microeconomic analysis (Ed. 21st). S. Chand
2. Keat, P. G., College, d., Erfle, S., Banerjee, S., & Young, P. K. Y. (2018). Managerial Economics (Ed. 7th). Pearson.
3. Dessler, G., & Varrkey, B. (2020). Human Resource Management (16th ed.). Pearson.
4. Koontz, H., Weihrich, H., & Cannice, M. V. (2020). Essentials of Management (Ed. 11th). McGraw Hill, New Delhi.
5. Pindyck, R. S., Rubinfeld, D. L., & Banerjee, S. (2022). *Microeconomics* (Ed. 9th). Pearson Education.
6. Koontz, H., Weihrich, H., & Cannice, M. V. (2020). *Essentials of Management* (11th ed.). McGraw-Hill.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2^{nd} Year (4^{th} Semester)	**Laboratory Practice in Heat Treatment**	MML 254	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60 Marks		40 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Illustrate the effect of the heat treatment process on the mechanical properties by studying microstructural evaluation and hardness measurements.
CO2	Identify the microstructures of different heat-treated steels.
CO3	Analyze the phase evolution in steels by using TTT and CCT diagrams.
CO4	Identification of suitable heat treatment process for the improvement in mechanical behaviour of materials.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	1. Comparative study of microstructure and hardness of the annealed, normalized and quenched steel samples. 2. To study the microstructure and hardness of tempered (High and low temperature) steel sample 3. To study the hardness and microstructure of steel samples in different quenching media- Water, oil and brine solution.	**6**
Module 2	4. To determine the hardenability of steel using the Jominy-end-Quench test. 5. Study of the isothermal transformations in Fe-C systems 6. To study the effect of case carburizing on the microstructure and hardness of steel samples 7. Precipitation hardening of aluminium-4%Cu alloy.	**10**
Module 3	8. Heat Treatment of Cast Iron- Malleabilization treatment of white cast Iron. 9. To study the microstructure and hardness of stepped quenched (Austempering and Martempering) steel samples 10. Comparison of microstructure and hardness of cold-worked and annealed sample (Steel, Aluminium)	**8**
Module 4	11. To investigate the phase transformation in steels by Dilatometry analysis 12. Application of the thermocalc software package in heat treatment of steels and HEAs.	**4**
	Total Hours	**28**

Year (Semester)	Course Title	Course Code	L-T-P-Credits
2^{nd} Year (4^{th} Semester)	**Laboratory Practice in Joining of Materials**	MML 255	0-0-2-1
Evaluation Policy	**Continuous Assessment**	**End-Term**	
	60 Marks	40 Marks	

Course Outcomes: At the end of course, students will be able to:

CO1: Demonstrate the use of gas, resistance and arc welding for ferrous and non-ferrous metals.

CO2: Contrast different welding techniques in terms of the strength of welded joints.

CO3: Differentiate the microstructure and strength in the fusion zone, HAZ, and base metal

CO4: Interpret the role of heat treatment for the welded components on microstructure and properties.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	1. Preparation and joining of two surfaces by soldering and brazing. 2. Welding of non-ferrous metals Aluminum, Copper and their alloys using Spot/Resistance welding.	**8**
Module 2	3. Gas welding of a given sample and Macro and Micro- examination of a welded joint. 4. Arc Welding of steel parts and their heat-treatment along with Macro and Micro-examination of a welded joint.	**8**
Module 3	5. Welding of dissimilar metals i.e. Steel, cast iron, Stainless Steel, Mild steel, etc and determination of microstructure.	**6**
Module 4	6. Determination of the strength properties of a welded joint and weld defects.	**6**
	Total Hours	**28**

3rd Year Syllabus

5th Semester

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (5th Semester)	**Corrosion Engineering**	MMT 301	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze the thermodynamic and electrochemical aspects of corrosion
CO2	Appraise the forms, mechanism, and kinetics of corrosion
CO3	Analyze the necessity of corrosion protection of materials for prevention of failures and sustainable material usage
CO4	Evaluate the mechanism of high temperature oxidation and hot corrosion of metals and alloys

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Corrosion Principles - Electrochemical aspects, Importance and cost of corrosion. Computation of corrosion rates, Thermodynamics of corrosion, Passivation, Mixed potential theory of corrosion and its application.	**8**
Module 2	Different Forms of Corrosion and Their Controls - Uniform Corrosion, Selective Corrosion Including Pitting Corrosion, Crevice Corrosion, Intergranular Corrosion, Filiform Corrosion, Stress Corrosion Cracking, Corrosion Fatigue, Fretting Corrosion, Cavitation Corrosion, Leaching, Erosion-Corrosion.	**12**
Module 3	Principle behind Protection of Materials against Corrosion: Cathodic and Anodic protection, inhibitors, coatings and design. Decorative coatings by electroplating. Corrosion Testing Methods. IS specification.	**12**
Module 4	High Temperature Corrosion & Oxidation of Metals And Alloys: Rate Laws, Kinetics and Mechanics. Wagner's parabolic law of Oxidation. Hot Corrosion, Corrosion in Mixed Gaseous Environment. High temperature materials.	**10**
	Total Hours	**42**

Books Recommended:

1. Corrosion Engineering, Greene, N.D.,M.G. Fontana ,Tata McGraw Hill,2005
2. Corrosion–For science and engineering, Kenneth R Trethewey and John Chamberlain, Longman Inc, 1996
3. Metallic corrosion and prevention, Raj Narayan, Oxford Publications, 1988
4. An introduction to Electro-metallurgy, Sharan & Narain, Standard Publisher, 1999
5. Corrosion and corrosion control – An introduction to corrosion science and engineering, Herbert H. Uhlig and R.Winston Revie, John Wiley & Sons, 1985
6. ASM handbook – Vol 13: Corrosion, ASM International, 2001
7. Principles and prevention of corrosion, Denny A. Jones, Prentice Hall Inc.,1996
8. Corrosion and corrosion protection handbook, Philip A. Schweitzer, ASM,1983

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rdYear (5thSemester)	**Iron Making**	MMT 302	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: Metallurgical Thermodynamics and Kinetics.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze the construction and design features of iron making blast furnace and its accessories.
CO2	Analyze heat and material balance of a blast furnace.
CO3	Calculate the carbon rate depending on the percentage of direct and indirect reduction, raceway adiabatic flame temperature and tuyere gas composition depending on the moisture content, oxygen content, and temperature of the blast.
CO4	Analyze different alternative routes of iron making.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Raw materials and their preparation (Sintering and pelletization). Blast furnace design and construction. Blast furnace stoves and blast preheating. Gas cleaning.	**10**
Module 2	Physical chemistry of iron making: Fe-O, C-O, Fe-C-O and Fe-C-O-H phase equilibria. Heat and Material balance, Blast Furnace slags and their behavior, slag-metal reactions, S and Si control. Irregularities in the Blast Furnace.	**14**
Module 3	Modifications in blast furnace: Bell-less charging system, high top pressure, humidification and Oxygen enrichment of blast, auxiliary fuel injection through tuyeres.	**10**
Module 4	Alternative methods of iron production: HYL, Midrex, Rotary kiln, Rotary hearth furnace, and Corex process.	**8**
	Total Hours	**42**

Books Recommended:

1. Principle of blast furnace ironmaking, A.K Biswas, SBA Publications, 2005.
2. Modern iron making, R.H. Tupkary, Khanna Publishers, 2008.
3. Iron Making and Steel Making – Theory and practice, Ahindra Ghosh and Amit chatterjee, PHI, 2008.
4. Sponge Iron production by direct reduction of iron oxide, Amit Chaterjee, PHI, 2010.
5. A first course in iron and steel making, D Mazumdar, Universities press, 2015.
6. The Iron Blast Furnace – Theory and Practice, Peacy and Davenport, Pergamon International Library.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (5th Semester)	**Mechanical Behaviour of Materials**	MMT 303	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Employ the constitutive equations/deformation equations to determine the effect of application of load
CO2	Analyse the effect of dynamic load and high temperature on the mechanical behaviour of materials
CO3	Evaluate the difference the elastic and plastic deformation
CO4	Estimate the mechanical properties of the material based on testing them at varied loading conditions

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Stress and Strain**: Index Notation, Analysis of Stresses and Strains – Two (Plane Stress/Strain)/Three-dimensional state, Sign Convention, Transformation of Axes, Principle stresses/strains, Mohr's Circles for stress/strain, Hydrostatic and Deviator Components of stress/strain, Elastic constants and their relationships, Isotropic Elasticity, Elastic Anisotropy, true Stress/Strain, Flow curve, Yield Criteria.	**15**
Module 2	**Dislocation Theory**: Deformation by Slip, critically resolved shear stress for slip, Dislocation Geometry and Energy, Dislocation Mechanics-Frank-Read Sources, Dislocation Pile-ups, Movement of Dislocations, Force on and between dislocations-Peach-Koehler equation, Dislocation Interactions, Yield-Point Phenomenon, Strain Hardening, Strain Aging, Strengthening from Grain Boundaries, Solid-Solution Strengthening, Strengthening from Fine Particles, Bauschinger Effect, Texture. Deformation by Twinning.	**16**
Module 3	**Testing of materials**: principles and its significance, Tensile Test- stress-strain curves (Engineering/True), Effect of strain rate, temperature on Flow Properties; Compression Test; Hardness Test-Rockwell, Brinell, Vicker, Microhardness Tests, Hardness-Conversion Relationships; Impact Test-Izod, Charpy, Ductile to Brittle Transition Temperature.	**3**
Module 4	**Fracture, Fatigue and Creep**: Types of Fracture, Stress-Intensity Factor, Theoretical Cohesive Strength of Materials, Griffith's Theory, Introduction to Fatigue – Surface observations, Nomenclature, S-N curve, Fatigue Design Considerations, LCF, HCF, Crack Propagation, Prevention and Creep – Creep curve, Structural Changes, Mechanisms, Extrapolation Schemes, Alloys for High Temperature use.	**8**
	Total Hours	**42**

Books Recommended:

1. Mechanical Metallurgy, Dieter G. E., Mc Graw Hill, 2013.
2. Mechanical Behaviour of Materials, William F. Hosford, Cambridge University Press, 2010.
3. Mechanical Behavior of Materials, T.H. Courtney, McGraw Hills, 1990.
4. Introduction to Dislocations, D. Hull & D.J. Bacon, Butterworth Heinemann, 2001.
5. Physical Metallurgy Principles, Robert E. Reed-Hill, Affiliated E-W Press Pvt. Ltd., 2008.
6. Mechanical Behavior of Materials, M. A. Meyers & K. K. Chawla, Prentice Hall, 1999.
7. Materials Science & Engineering: An Introduction, William D. Callister, Jr., John Wiley & Sons, Inc., 2007.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (5th Semester)	**Materials Characterization**	MMT 304	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify the working principles, instrumentation and application of various characterization techniques
CO2	Choose an appropriate sample preparation method for various characterization techniques
CO3	Analyze microstructure of materials at different length scales
CO4	Evaluate the materials crystal structure, grain size, composition and phases by using XRD, microscopy and spectroscopic techniques

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Optical microscopy:** Introduction, Image formation, concept of resolution, numerical aperture, empty magnification, depth of field and focus, lens aberrations, components of microscope- illumination system, objective lens and eyepiece, etc.; specimen preparation for optical microscopy; Imaging mode- bright-field and dark-field, principles and application of polarized, phase contrast and interference microscopy; quantitative microscopy- estimation of grain size, volume fraction and grain boundary area	**10**
Module 2	**X-ray diffraction (XRD):** Brief review of crystal structure; Production and properties of X-ray, Bragg's law, diffraction intensities, factors affecting intensity, structure factor calculations- SC, BCC, FCC. NaCl structure, etc., Working principles and components of an X-ray diffractometer; application of XRD – Indexing of XRD patterns, determination of crystallite size and lattice strain, residual stress measurement	**10**
Module 3	**Electron Microscopy:** Introduction, interaction of electrons with the specimen. ***Scanning electron microscopy (SEM):*** working principle, construction and operation of SEM; sample preparation; different detectors, modes of operation, image formation of plane and fractured surfaces, elemental analysis by EDS. ***Transmission electron microscopy (TEM):*** Construction and working principles of TEM; specimen preparation technique for TEM; principles of electron diffraction in TEM, bright and dark field imaging, selected area diffraction patterns and indexing.	**15**
Module 4	**Additional Characterization techniques**: Elemental analysis by X-ray fluorescence (XRF) spectrometry, Atomic force microscopy, Electron probe microanalysis (EPMA)	**7**
	Total Hours	**42**

Books Recommended:

1. Metallography, principle and practice ,Vander Voort, Mc Graw Hill,1984
2. Elements of X-ray Diffraction, B.D. Cullity, Addison–Wesley Publishing Company, 2001
3. Electron Microscopy and Analysis, P.J Goodhew J. Humphreys R Beanland, Taylor and Francis, 2001
4. Fundamentals of light microscopy and electronic imaging, Douglas B. Murphy, Wiley-Liss, Inc. USA, 2001
5. Scanning Electron Microscopy and X-Ray Microanalysis: J Goldstein and Dale E. Newbury, Springer, 2011
6. X-ray diffraction, C. Suryanarayana, M. G. Norton, Springer US, 1998
7. Materials characterization, Yang Leng, JohnWiley & Son, 2008
8. David B. Williams, C. Barry Carter, " Transmission Electron Microscopy: A Textbook for Materials Science", Springer, pub. 2009.
9. ASM Handbook, Volume 10, Materials Characterisation, Whan R E (Ed), ASM international,1986

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (5th Semester)	**Laboratory Practice in Corrosion Engineering**	MML 308	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60		40

Course Outcomes:

CO1	To articulate the morphology of corroded samples and interpret the galvanic corrosion of metals by weight loss method.
CO2	To evaluate the effect of cathodic protection on given metallic samples and examine the influence of various inhibitors on corrosion protection
CO3	To evaluate the working principle of potentiostat
CO4	To categorize the high temperature oxidation of metals/alloys.

Module No.	Contents	Hours
Module 1	1. To examine the microstructure of a corroded sample. 2. To identify the type of the corrosion. 3. To understand the working principle of the pH meter.	**7**
Module 2	4. To study the galvanic corrosion of metals by weight loss method. 5. To study the effect of cathodic protection on given couple of metallic samples.	**7**
Module 3	6. To study the influence of various inhibitors on corrosion protection. 7. To understand the working principle of potentiostat. 8. To investigate the effect of aqueous corrosion on a given sample.	**8**
Module 4	9. To study the High temperature oxidation of different metals. 10. To study the High temperature oxidation of different alloys.	**6**
	Total Hours	**28**

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (5th Semester)	**Laboratory Practice in Mechanical Behaviour of Materials**	MML 309	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60 Marks		40 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Determination of mechanical properties of a material using different techniques
CO2	Infer the physical meaning of the mechanical property values of materials
CO3	Compare the material's response to various loading conditions
CO4	Analyse the results and assess the reasons for the observed results

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	1. To prepare metal samples for hardness tests 2. To determine Rockwell Hardness Number of metal specimen 3. To determine Brinell Hardness Number of metal specimen 4. To determine Vicker Hardness Number of some alloys/steel specimen 5. To compare the hardness values of different metal samples using different hardness techniques 6. Discussion of the results obtained	**10**
Module 2	7. To determine the materials response to tensile load till failure 8. To obtain material property values using tensile stress-strain curve 9. Discussion of the results obtained	**4**
Module 3	10. To determine the materials response to compressive load till failure 11. To obtain material property values using compressive stress-strain curve 12. Discussion of the results obtained	**4**
Module 4	13. To determine energy absorbed by the material by performing Izod Test 14. To determine energy absorbed by the material by performing Izod Test 15. To compare the results of the Izod and Charpy Tests 16. Discussion of the results obtained	**6**
Module 5	17. To determine the materials response to dynamic loading i.e., fatigue test 18. To obtain material property values using S-N curve 19. Discussion of the results obtained	**4**
	Total Hours	**28**

Books Recommended:

1. Mechanical Metallurgy, Dieter G. E., Mc Graw Hill, 2013.
2. Mechanical Behaviour of Materials, William F. Hosford, Cambridge University Press, 2010.
3. Materials Science & Engineering: An Introduction, William D. Callister, Jr., John Wiley & Sons, Inc., 2007.

Year (Semester)	Course Title	Code:	L-T-P-Credits
3rd Year (5th Semester)	**Laboratory Practice in Materials Characterization**	MML 310	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End - Term**
	60 Marks		40 Marks

Course Outcome:

CO1:	Ability to prepare the specimens for microstructural analysis
CO2:	Analyze the operation of the XRD, optical and electron microscopy
CO3:	Analyze the microstructural features of different alloys by using optical and electron microscopes
CO4:	Understand and interpret the grain size of the specimens by using different techniques

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	1. Determination of chemical composition of metallic sample by emission spectroscopy.	**2**
Module 2	2. To prepare the metallic sample for metallographic examination. 3. Determination of grain size using conventional and other techniques.	**6**
Module 3	4. Determination of cubic crystal structure using powder XRD. 5. Precise lattice parameter determination using XRD. 6. Estimation of crystallite size using Scherrer formula.	**8**
Module 4	7. Ductile and brittle fracture surface study using scanning electron microscope	**2**
Module 5	8. Chemical analysis using energy dispersive spectroscopy (EDS) analysis in SEM & XRF.	**4**
Module 6	9. DSC/DTA analysis. 10. TGA analysis.	**6**
	Total Hours	**28**

Professional Elective I

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (5th Semester)	**(Professional Elective 1)** **Advanced Manufacturing Processes**	MMT 001	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply the advanced manufacturing processes in the production of new material objects.
CO2	Analyze the advanced manufacturing processes in the production of new material objects.
CO3	Evaluate the advanced manufacturing processes in the production of new material objects.
CO4	Categorize the Measurement techniques in micromachining.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction to Advanced Manufacturing Processes (AMP):** Introduction, need of advanced manufacturing processes, advantages, disadvantages, limitation and applications of AMP, and recent development in respect of India	**6**
Module 2	**Advanced Welding, Casting and Forming Processes:** Friction Stir Welding-Introduction, Tooling, Temperature distribution and resulting melt flow, Advanced Die Casting-Vacuum Die Casting, Squeeze Casting, Roll forming, High velocity hydroforming, High velocity mechanical forming, Electromagnetic forming, High energy rate forming (HERF), Spinning, Flow forming, Shear Spinning	**10**
Module 3	**Advanced techniques for Material Processing:** STEM: Shape Tube Electrolytic Machining, EJT: Electro Jet Machining, ELID: Electrolytic In-process Dressing, ECG: Electrochemical Grinding, ECH: Electro-chemical Etching laser-based Heat Treatment, Micro Machining Processes: Diamond micro machining, Ultrasonic micro machining, Micro electro discharge machining, Special purpose machining (SPM)	**10**
Module 4	**Additive Manufacturing Processes:** Introduction and principles, classification of AM, Benefits of AM, advantages, disadvantages, limitations, Development of additive manufacturing technologies, General additive manufacturing processes, selective laser sintering (SLS), Powder based fusion process, Extrusion based system, Sheet lamination process, Direct write technologies	**10**
Module 5	**Measurement Techniques in Micro Machining:** Introduction, Classification of measuring system, Microscopes: Optical Microscope, Electron Microscopes, Laser based system, Interference Microscopes and Comparators, Surface profiler, Scanning Tunneling Microscopes, Atomic Force Microscopes, Applications	**6**
	Total Hours	**42**

Books Recommended:

1. V. K. Jain, Advanced Machining Processes, Allied Publishers,2009.
2. Hassan El-Hofy, Advanced Machining Processes, McGraw-Hill Prof Med/Tech, 2005.
3. Helmi Youssef, Non-Traditional and Advanced Machining Technologies, CRC Press, 2020.
4. I. Gibson l D. W. Rosen l B. Stucker, Additive Manufacturing Technologies Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010.
5. Damir Godec, A Guide to Additive Manufacturing, Springer, 2022.
6. Mikell P. Groover, FUNDAMENTALS OF MODERN MANUFACTURING, Materials, Processes, and Systems, Fourth Edition, 2010

Year(Semester)	Course Title	Course Code	L- T- P-Credits
3rd year (5th Semester)	**(Professional Elective 1)** **Physical Metallurgy of Light Metals and Alloys**	MMT 002	2-1-0-3
Evaluation Policy	**Mid-Term**	**Class Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None

Course outcomes: At the end of the course, the student will be able to

CO1	Appreciate the role of light metals for energy savings in different applications/sectors.
CO2	Analyze the physical metallurgy of cast and wrought Aluminum alloys
CO3	Analyze the physical metallurgy of Magnesium and Titanium alloys
CO4	Evaluate the physical metallurgy of novel materials such as light metal matrix composites and metallic foams

Detailed Syllabus

Module No.	Contents	Hours
Module 1	**Introduction**: Definition of light metals, cast and wrought alloys, characteristics of light metals and alloys, trends in applications. Light metal matrix composites, metallic foams and nanophase alloys.	**10**
Module 2	**Physical metallurgy of aluminum alloys:** Work hardening and annealing, forming limit curves, textures, principles of age hardening, micro-alloying effects, hardening mechanisms, aging processes, mechanical behavior, corrosion behaviour. **Wrought aluminum alloys:** Designation and tempers, heat treatable and non-heat treatable alloys, Li containing alloys, joining, special products- aircraft alloys, automotive alloys, packaging alloys, electrical conductor alloys. **Cast aluminum alloys:** Designations, tempers and characteristics, alloys based on Al-Si, Al-Cu, Al-Mg, Al-Zn-Mg systems, modification in Al-Si alloys, joining	**16**
Module 3	**Magnesium alloys**: Introduction to alloying behavior, alloy designations, Zr-free and Zr-containing alloys, wrought magnesium alloys, extrusion alloys, forging alloys, trends in applications of Mg alloys, electrochemical aspects **Titanium alloys:** Introduction and classification, basic principles of heat treatment, alpha alloys, α/β alloys, beta alloys, wrought and cast commercial titanium alloys, texture effects, surface treatments, engineering performance- tensile, creep, and fatigue behaviour, applications- general applications, aerospace, power generation, automotive, marine, biomaterials.	**16**
	Total Hours	**42**

Books Recommended

1. Polmear I.J., Light Alloys, 4th Ed., Elsevier 2004
2. Brandes E.A. and Brook G.B., Smithells Light Metals Handbook, Elsevier 1998

Honours Elective I

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (5th Semester)	**(Honours elective 1) Introduction to Energy Materials**	MMT 003	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Interpret the working principles of modern devices for energy storage and conversion
CO2	Analyse the limitations, existing issues and wider aspect concerning commercialization of advanced devices
CO3	Interpret the basic principles of functioning of devices for electrochemical conversion and storage
CO4	Compare the physical-chemical mechanisms for the devices during their operation.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction -** Ragone charts, necessity of energy storage, specifications of energy storage devices, self-discharge time, unit size, efficiency, cycle life, specific energy, energy density.	**10**
Module 2	**Energy Storage Methods -** Mechanical energy storage, compressed air energy storage, flywheel storage, secondary battery storage, lead–acid battery, limitations of lead–acid storage batteries, sulfation, acid stratification, valve regulated lead acid battery, nickel–cadmium (Ni–Cd) battery, nickel–metal hydride (Ni–MH or Ni–MH) battery, lithium–ion battery (LIB), lithium–polymer battery, sodium–sulphur battery, ZEBRA battery, flow batteries, vanadium redox flow battery, polysulfide bromide battery, zinc bromide flow battery, supercapacitor.	**15**
Module 3	**Fuel Cells and Types -** Development stages and relative performances of various fuel cells, fuels for fuel cells, efficiency of a fuel cell, characteristics of fuel cell, fuel cell power plant, present status, environmental effects, phosphoric acid fuel Cell (PAFC), alkaline fuel Cell (AFC), polymer electrolyte membrane fuel cell (PEMFC), direct methanol fuel cell (DMFC), molten carbonate fuel cell (MCFC), solid oxide fuel cell (SOFC).	**10**
Module 4	**Hydrogen as Energy Carrier -** Properties of hydrogen, production, electrolysis of water, thermolysis of water, biophotolysis, storage, delivery, conversion.	**7**
	Total Hours	**42**

Books Recommended:

1. Non-Conventional Energy Resources/ B.H. Khan/ McGraw Hill Education (India) Private Limited/ 3rd edition, 2016
2. Electrochemical Energy Advanced Materials and Technologies/ Jiang, San Ping Shen, Pei Kang Sun, Xueliang Wang, Chao-Yang Zhang, Jiujun / Wiley-ISTE/ 1st edition, 2015

Year (Semester)	Course Title	Code	L-T-P-Credits
3rd Year (5th Semester)	**(Honours elective 1) Transport Phenomena in Materials Engineering**	MMT 004	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End - Term**
	26 Marks	24 Marks	50 Marks

Course Outcomes

CO1:	Apply the basics and scientific aspects of fluid flow to understand industrial problems.
CO2:	Apply the transport concepts and equations of fluid flow, heat transfer and mass transfer for various metallurgical processes.
CO3:	Relate the convert actual (descriptive) processes with appropriate equations.
CO4:	Develop clear understanding and attempt to solving different numerical pertaining to heat transfer, mass transfer and fluid flow.

Detailed Syllabus

Module Number	Contents	Hours
Module 1	**Fluid dynamics** Introduction to Transport phenomena in materials processing and metallurgical engineering, Newton's law of viscosity, Reynold's Transport Theorem, Transport Equations, Equation of continuity, Navier Stokes equations, Numerical problems on metals and materials processing.	**10**
Module 2	**Heat transfer** Fundamentals of conduction heat transfer, Laws and equations, Steady and unsteady heat conduction, Conductive heat transfer through composite wall, cylinder, sphere, Fundamentals of convective heat transfer; free and forced convective heat transfer, Fundamentals of Radiation heat transfer and rate laws, Problems on Radiation heat transfer. Transient Heat Transfer, Lumped Analysis, Fin Analysis	**12**
Module 3	**Mass Transfer** Fundamentals of diffusion, rate laws, Uphill diffusion and Kirkendal's effect, steady and unsteady diffusion, Fundamentals of convective mass transfer; free and forced convective mass transfer, and mass transfer coefficient, Problems on Convective mass transport, Mass transfer between two fluids (two film theory, surface renewal theory, penetration theory etc) and there numericals, Diffusion in gases through porous solid.	**12**
Module 4	**Application of heat transfer** in: Heat treatment, solidification, cooling of slabs, heat flow through refractory walls etc, **Application of mass transfer** in: case hardening, doping of semiconductors, homogenization, oxidation, absorption/desorption of gases in liquid metals, dimensional analysis.	**08**
	Total Hours	**42**

Recommended Books:

1. Rate Processes in Metallurgy, Mohanty AK, PHI, 2000
2. Fundamentals of Engineering Heat and Mass Transfer, Sachdeva, R C, New Age International, 1996
3. Fundamentals of heat and Mass Transfer, Kothandaraman C P., New Age International,1997
4. Transport Phenomena, Bird R.B, Stewart E.S and Light foot, John Wiley & Sons, 2002
5. Transport Phenomena in Metallurgy, Geiger GH and Poirier DR, Addison Wesley, 1973

Open Elective I
for
Non-MMED Students

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (5th Semester)	**Electrical and Electronic Engineering Materials**	MMT 016	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Interpret the atomic structure of materials and correlate with properties
CO2	Analyse the semiconducting properties of materials
CO3	Apply the principles of magnetism to design magnetic materials
CO4	Demonstrate the use of optical properties of materials for performance

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Crystal Structure:** Atomic structure, Electronic configuration, Periodic table, Ionic, Covalent, Metallic bonding, Crystalline nature of solids, Lattice Points, Unit Cell, Bravais Lattices, Crystal structure: SC, BCC, FCC and HCP, APF, Theoretical density, Crystallographic direction and planes, Linear and Planar densities.	**10**
Module 2	**Electrical & Dielectric Properties:** Ohm's Law, Electrical resistivity and conductivity, Current density, Electron energy, valence, conduction band, Fermi energy, Electron mobility, Drift velocity, Dielectric Behaviour, Capacitance, Dielectric constant, Electric dipole, polarization, Surface charge density, dielectric displacement, Types of polarization, Dielectric strength, Dielectric materials, Piezoelectricity	**12**
Module 3	**Magnetic Properties:** Origin of magnetic dipole, Bohr magnetrons, Magnetic field vectors, Magnetic flux density, Magnetic field strength, permeability, Magnetization, magnetic susceptibility, Diamagnetism, Paramagnetism and Ferromagnetism, Curie temperature, Domains and Hysteresis, Hysteresis Curve, Remanence, Coercivity, Magnetic anisotropy, Soft Magnetic Materials, Hard Magnetic Materials. Important carbon steels and precipitation hardening type magnet. Superconductivity, Classification of superconductors- Meissner effect, Applications.	**12**
Module 4	**Optical Properties:** Electromagnetic radiations, Photon, Light Interactions with solids, Atomic and Electronic Interactions, Electronic polarization and transitions, Optical properties of Metals – Photon absorption and reemission during excitation of electron, Optical properties of Non-metals – Refraction, Reflection, Absorption and Transmission. Application of Optical phenomena – Luminescence, Fluorescence, Phosphorescence, Light emitting diodes, Photoconductivity.	**8**
	Total Hours	**42**

Books Recommended:

1. William D. Callister, Jr. David G. Rethwisch : Material Science and Engineering – An introduction, 8th Edition John Wiley & Sons, Inc.
2. V. Raghavan: Material Science and Engineering , 8th Edition PHI Learning Private Limited, New Delhi
3. Dekker A. J: Electrical Engineering Materials, PHI Learning Private Limited (1970)
4. Indulkar C. S.: An Introduction to Electrical Engineering Materials, Revised Edition S Chand & Co Ltd
5. Banerjee G.K: Electrical and Electronics Engineering Materials, PHI Learning Private Limited (2014)

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (5th Semester)	**Introduction to Materials Science & Engineering**	MMT 017	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyse the various types of materials and bonds
CO2	Analyze various metallurgical processes in materials
CO3	Apply various processes for the extraction/production of various materials
CO4	Analyse the phase diagrams of binary systems

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	An introduction to Metallurgy and Classification of Metallurgical Processes. Classification of Engineering Materials based on Engineering properties. A general discussion on other engineering materials plastics, rubber, polymers, ceramics, refractories, glasses, composites.	**10**
Module 2	Bonding in solids, crystal structure & imperfections. Plastic deformation in single crystals. Brief discussion on plastic deformation & Strain Hardening.	**10**
Module 3	A brief discussion on important ferrous and non-ferrous materials and their extraction/production processes (flow sheets giving important parameters).	**8**
Module 4	General introduction to phase rule and phase diagrams (Binary systems). An overview of iron carbon equilibrium diagram and the critical phenomenon.	**8**
Module 5	Introduction of Nano-technology; its importance and applications.	**6**
	Total Hours	**42**

Books Recommended:

1. Material Science and Engineering, Callister published by John Wiley, 2008
2. Principles of Material Science and Engineering, Smith published by Mc Graw Hill, 1990
3. Materials Science and Engineering, V. Raghavan, published by PHI, 2008
4. Engineering Materials Science, Richards, published by Wadsworth Pub. Co., 1961.
5. Material Science, R. S. Khurmi & R. S. Sedha published by S. Chand, 2005.

6th Semester

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Ceramic Technology**	MMT 351	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Course Outcomes:

CO1	To apply the concepts of structure, imperfections, phase diagrams, sintering, fabrication, and properties on ceramic materials.
CO2	To analyze the concepts of structure, imperfections, phase diagrams, sintering, fabrication, and properties on ceramic materials.
CO3	To appraise the concepts of structure, imperfections, phase diagrams, sintering, fabrication, and properties on ceramic materials.

Detailed Syllabus:

Module	Content	Hours
Module 1	Introduction to ceramics, Structural characteristics of ceramics and glasses, structural imperfections, surfaces, interfaces and grain boundaries.	**14**
Module 2	Atom mobility, ceramic phase equilibrium diagrams, phase transformation, glass formation and glass ceramics, reactions with and between solids.	**14**
Module 3	Grain growth, sintering and vitrification, microstructure of ceramics, fabrication processes and mechanical properties.	**14**
	Total Hours	**42**

Recommended Books:

1. Fundamentals of Ceramics by Michael Barsoum, Mc Graw Hill Publishing Co, 1997
2. Foundations of Materials Science and Engineering by William F.Smith, McGraw-Hill Inc, New York, 1993
3. Introduction to Fine Ceramics by Nobuka Ichinose, John Wiley, 987
4. Introduction to Ceramics by Kingery, W D, John Wiley, USA, 2012
5. Modern Ceramic Engineering by D W Richerson & W E Lee, CRC Press 4th edition, 2018

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Steel Making**	MMT 352	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: Metallurgical Thermodynamics and kinetics, Ironmaking.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze the methods of removal of impurities during steelmaking.
CO2	Compare different steel making processes like LD, LDAC, KALDO, ROTOR, Open hearth, Electric arc furnace, and induction furnace.
CO3	Analyze processes for the production of clean steel.
CO4	Investigate the defects observed in ingot and continuous casting, suggest remedial actions for them.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Brief history and earlier methods of steel making. Current scenario of iron and steel industries in India and World. External De-siliconisation and desulphurization of pig iron. Physico-Chemical principles of steel making.	**12**
Module 2	Steel making by Bessemer and side blown converters, Open Hearth and Duplex/Triplex methods, Electric-Arc and Induction process. Basic oxygen processes – LD, LDAC, KALDO, ROTOR, OBM, etc. Stainless steel production.	**12**
Module 3	Secondary Steel making: Inert gas purging, Inclusions and their control, De-oxidation and vacuum treatment of steels, Injection metallurgy, Post-solidification treatments.	**8**
Module 4	Steel casting practice: Ingot mould and base plate preparation for casting. Ingot defects and their control. Continuous casting practice of steel and recent advances.	**10**
	Total Hours	**42**

Books Recommended:

1. Iron Making and Steel Making – Theory and practice, Ahindra Ghosh and Amit Chatterjee, PHI, 2008.
2. Introduction to Modern Steel Making, R.H. Tupkary, Khanna Publishers, 1994.
3. The Making, Shaping and Treating of Steel, R J Fruehan, AISE Steel Foundation, 1998.
4. A first course in iron and steel making, D Mazumdar, Universities press, 2015.
5. Secondary steelmaking: principles and applications, Ahindra Ghosh, CRC press, 2000.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Powder Metallurgy**	MMT 353	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze the various powder fabrication processes and effect of particle characteristics on compressibility and consolidation of powders.
CO2	Analyze various powder compaction techniques utilized in various industries: automotive and aerospace industries, jewels & decorative industries
CO3	Evaluate the importance of sintering, sintering atmosphere & factors influencing sintering in powder metallurgy
CO4	Create various powder products –Metallic filters, carbide tools, magnetic, refractory, bearing & composite materials

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Production of Metal Powders:The importance of Powder Metallurgy. Various methods of producing metal powders. Characteristics of metal powders and their correlation with the various methods of production. Hazards in metal powder production.	**11**
Module 2	Testing of Metal Powders: Testing and classification of powders. Treatment of metal powders prior to compacting - Mixing and conditioning of metal powders.	**10**
Module 3	Compaction Techniques: Cold and hot compaction and their limitations. Design of dies. Rolling, slip casting, forging and extrusion of metal powders. Explosive compaction. Factors influencing the properties of compacts.	**10**
Module 4	Sintering: Sintering - its significance in powder metallurgy, sintering environments, importance of controlled atmosphere for sintering. Sintering equipment and their classification. Factors influencing sintering of metal powders. Techniques of activated sintering. Post sintering operations and the properties of sintered products/ compacts. Various powder products including dense, porous, hard, refractory, magnetic, dispersion strengthened and composite materials	**11**
	Total Hours	**42**

Books Recommended:

1. Powder Metallurgy: Science Technology and Applications, Angelo P C & Subramanian, PHI, 2012
2. Powder Metallurgy, Sinha A K, Dhanpat Rai & Sons, 1982
3. Powder Metallurgy Applications, Advantages and Limitations, Erhard Klar, American Society for Metals, 1983
4. Powder Metallurgy Opportunities for Engineering Industries, Ramakrishnan , Oxford and IBH Publishing Co PvtLd, 1987
5. Metals Handbook, Vol.7, Powder Metallurgy, Metals Park, Ohio, USA
6. Powder Metallurgy by B.K.Datta, An advanced Technique of Processing Engineering, Second edition, PHI Learning Private Limited, Delhi-2014

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Mechanical Working of Materials**	MMT 354	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Classification of metalworking processes and analysis of various factors involved in forming metals into useful shapes.
CO2	Assess the mechanics of metalworking operation.
CO3	To examine the defects created in materials due to different metal/polymer working operations.
CO4	Discuss the effects of metalworking processes on the mechanical properties of materials.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Metal working:** Classification of metal working (forming processes, mechanics of metal working, flow stress determination, temperature in metal working, effect of strain rates, metallurgical structure. Friction and lubrication. Workability, residual stresses.	**10**
Module 2	**Bulk Metal Forming Processes:** Rolling, Classification of rolling processes, Mechanics of rolling, defects in rolled products. Extrusion, Classification of extrusion processes, extrusion equipment, mechanics of extrusion, defect in extruded products. Forging, Classification of forging processes, forging equipment, Analysis of forging, forging defects. Drawing of rods, wires and tubes, Rod wire and tube drawing processes, drawing equipment, defects in rods wires and tubes. Analysis of forces operative during metal working processes.	**17**
Module 3	**Sheet Metal forming:** Forming methods; shearing, blanking, bending, stretch forming, deep drawing, defects in formed parts, Analysis of forces required for sheet metal forming.	**10**
Module 4	**Non-conventional Forming Methods:** HERF Processes, Explosive Forming, Magnetic Forming, Electric discharge forming, Laser Forming.	**5**
	Total Hours	**42**

Books Recommended:

1. Mechanical Metallurgy, Dieter G. E., Mc Graw Hill, 2013.
2. Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Mikell P. Groover, John Wiley & Sons, Inc, 2010.
3. Mechanical Properties and Working of Metals and Alloys, Amit Bhaduri, Springer Series in Materials Science -264, 2018.
4. Handbook of Metal Forming, Kurt Lange, Society of Manufacturing Engineers, Michigan, 1988.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Laboratory Practice in Ceramic Technology**	MML 358	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60		40

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze the properties of ceramic materials
CO2	Synthesize ceramics materials via powder metallurgy
CO3	Assess the effect of various parameters such as powder size, pressure and firing temperature on the ceramics product
CO4	Evaluate the different phases in ceramic microstructure

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	1. Powder Preparation – Crushing of fireclay grog, Size distribution of grog 2. Determination of Packing Density of refractory raw materials 3. Fabrication of refractory bodies using best packed refractory raw materials.	**5**
Module 2	4. Firing of refractory bodies at different temperature 5. Study of effect of Composition, Forming pressure & Firing temperature on some properties of refractory bodies.	**6**
Module 3	6. Testing of various important properties of refractories as per IS. 7. Spalling Resistance Test (Thermal Shock Resistance) of refractory bodies. 8. Refractory corrosion test	**6**
Module 4	9. Outline of general Method of preparation of Ceramic powder materials: (a) Sol Gel Method (b) Precipitation and Co-Precipitation technique. 10. Ceramic powder preparation: (a) Micron alumina (b) Silica Gel and precipitated Silica (c) $MgAl_2O_4$ Spinel (d) Mullite (e) Ferrite	**6**
Module 5	11. Characterization of Ceramic powder: (a) Tap density (b) DTA / TGA / DTGA (c) Raman Spectroscopy (d) Particle Size Analysis	**5**
	Total Hours	**28**

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Laboratory Practice in Mechanical Working of Materials**	MML 359	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60 Marks		40 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Examine the various metal working processes
CO2	Infer the physical meaning of the mechanical property values of materials
CO3	Measure the mechanical property value changes due to various mechanical working processes
CO4	Analyse the results and assess the reasons for the observed results

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	1. To prepare metal samples for wire drawing. 2. To perform wire-drawing operation on wires of different metals 3. To compare ductility of ferrous and non-ferrous materials with regards to wire drawing. 4. Discussion of the results obtained	**6**
Module 2	5. To perform rolling operation on metal specimen 6. To evaluate the change in hardness with increase in the number of passes 7. To perform tensile test on rolled specimen and determine the change in mechanical properties with increase in the number of passes 8. To analyse the change in microstructure due to increase in the rolling passes 9. Discussion of the results obtained	**8**
Module 3	10. To determine the cupping index of sheet metal 11. To analyse the propagation of crack in the sheet metal 12. Discussion of the results obtained	**4**
Module 4	13. To perform forging on metal samples 14. To evaluate the change in hardness with increase in the number of strokes 15. Discussion of the results obtained	**4**
Module 5	16. To perform shearing on metal samples 17. Discussion of the results obtained	**4**
Module 6	18. To perform bending on metal samples 19. Discussion of the results obtained	**2**
	Total Hours	**28**

Books Recommended:

1. Mechanical Metallurgy, Dieter G. E., Mc Graw Hill, 1988.
2. Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Mikell P. Groover, John Wiley & Sons, Inc, 2010.
3. Physical Metallurgy Principles, Robert E. Reed-Hill, Affiliated E-W Press Pvt. Ltd., 2008.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Industrial Training / Internship**	MMI 360	0-0-2-1
Evaluation Policy (weightage)	Presentation and response to questions/queries raised		Report Submission
	70%		30%

Course Outcomes: At the end of the course, the student will be able to:

CO1	The students should be able to develop an understanding of the actual working environment.
CO2	To enhance their knowledge and skill from what they have learned in college and its implemen in different industries.
CO3	To imbibe the good qualities of integrity, responsibility and self-confidence required in industri

Details

1. Each student will be required to undertake practical training during the winter vacations for about 10-16 weeks in metallurgical industries. Each student will submit a training report in the department and give details of the jobs he was assigned during the practical training at the industry where he has taken such practical training. Separate reports for the training taken at different industries will be required to be submitted by each candidate.

2. The students will also be required to go for a long industrial/educational tour to visit various industries and educational Organisations of Metallurgical concern. Each student will submit a tour report on completion of the tours.

3. The tour and training report as submitted by each student will be assessed by the staff members and evaluated for sessional awards.

4. A viva-voce examination will be conducted by an Examiner for assessment of Tour and Training undertaken by each student and for his/her professional achievements, Group discussing during the 5 th semester course work.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Seminar**	MMS 361	0-0-2-1
Evaluation Policy (weightage)	Presentation and response to questions/queries raised		Report Submission
	70%		**30%**

Course outcomes:
The student should be able:

CO1	To improve their oral communication skills
CO2	To become aware of recent advancement in the field of Metallurgical and Materials Engineering

Details:
1. A co-curricular activity based on seminar talks. This will involve a detailed study of a topic of interest and production in the candidates own style. Each student will be required to give a seminar talk on the subject of his/her interest. The handouts of the talks will be submitted by the student before the talk is delivered. These seminar talks will prepare the students for a proper survey of literature, compilation of information so gathered and presentation of the same to the audience. The handouts submitted by the students will be in accordance with the standard of technical papers.

2. The award of the session will be based on the preparation and presentation of seminar talks and performance in the group.

Professional Elective II

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**(Professional Elective 2) Thermal Analysis & Spectroscopy**	MMT 050	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply the thermal analysis techniques to assess the evolution of microstructure in materials.
CO2	Analyze the microstructure and its influence on the properties of ferrous and non-ferrous alloys.
CO3	Evaluate the structure-property correlationship of the material.
CO4	Design an experiment strategy on the basis of temperature and composition of the material.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Thermal Analysis Techniques** Working principle, application & analysis technique of Differential Scanning Calorimetry (DSC), Differential Thermal Analysis (DTA), Dilatometry, Thermogravimetric Analysis (TGA).	**15**
Module 2	**Spectroscopy Techniques** Working principle, application and analysis technique of Raman spectroscopy, UV-Vis Spectroscopy, FTIR Spectroscopy Analysis, Atomic Absorption Spectroscopy, X-ray Photoelectron Spectroscopy (XPS), Optical emission spectroscopy, Inductive coupled plasma spectroscopy. Auger spectroscopy, Gas chromatography and mass spectroscopy (GCMS), CHNS/O analysis, Wavelength dispersive spectroscopy.	**17**
Module 3	**Case studies**: Relevant case studies based on thermal and spectroscopic analysis	**10**
	Total Hours	**42**

Books Recommended:

1. Materials characterization, Yang Leng, JohnWiley & Son, 2008
2. ASM Handbook, Volume 10, Materials Characterisation, Whan R E (Ed), ASM international,1986
3. Thermal Analysis in Practice, Matthias Wagner, Hanse Publications, 2018

Year (Semester)	Course Title	Code	L-T-P-Credits
3rd Year (6th Semester)	**(Professional Elective 2)** **Fuels, Furnaces and Refractories**	MMT 051	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End - Term**
	26 Marks	24 Marks	50 Marks

Course Outcomes:

CO1	Explain the difference between solid, liquid, and gaseous fuels and their manufacturing process and uses.
CO2	Explain the fundamentals of refractories and metallurgical furnaces.
CO3	Explain the construction and working principles of different types of furnaces and refractories.
CO4	Develop a clear understanding of Future advancement in Continuous Casting, furnaces, and Refractories used in India.

Detailed Syllabus

Module Number	Contents	Hours
Module 1	**Fuels:** Their classifications and resources in India, their importance in human life, Comparative study of solid, liquid, and gaseous fuels, constitution, classification and grading of coal, Metallurgical Coke and its properties and production, carbonization, testing of fuels.	**10**
Module 2	**Furnaces:** Their classification. Elements of furnace construction, Batch type and continuous furnaces, fuel economy, heating and heat saving methods, Furnace design, Furnace temperatures and Furnace atmospheres and their control, Evolution of heat and flame temperature, Available heat, Combustion of fuels, and problems based on air supplied, excess air and products of combustion. Natural, forced, induced, and balanced draft. Chimney Height. Heat losses in furnaces and Minimization, Waste Heat Recovery. Various types of Heating Elements and Electric Furnaces viz. Resistance, Arc, and Induction furnaces.	**15**
Module 3	**Refractories:** Their classifications, compositions, structures, properties, and applications, Manufacture of Acid, Basic and Neutral Refractories, Special Refractories like Graphite, Zirconia, Thoria, silicon carbide, etc., Testing and Quality control of Refractories. Methods for production of fireclay, silica, Magnesite, Chrome-magnesite, dolomite, and insulating bricks, their compositions, properties, and Applications.	**12**
Module 4	Selection of fuel, furnaces, & refractories for Metallurgical Applications from environmental aspects.	**05**
	Total Hours	**42**

Text Books

1. Fuels, Brame and King, ASTM, Philadelphia, 1967
2. Refractories, Norton F.H, Tata Mc Graw Hill, 1984
3. Refractories- production, properties and applications, Chesti A.R , PHI, 1986
4. Industrial furnaces, Trinks W., John Wiley and Sons, 2004
5. Elements of Fuels Furnaces and Refractories, O.P.Gupta, Khanna Publications, 1993
6. Refractories Production and Properties, Chester, IOM, 1973

Honours Elective II

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**(Honours elective 2) Protective Coatings**	MMT 052	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Categorize the coatings for engineering applications
CO2	Assess the role of protective coatings for engineering applications
CO3	Select and apply protective and functional coatings on different substrates
CO4	Investigate the failure mechanisms in the coatings and maintenance for industrial applications

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Requirement of protective coatings, classification of organic, polymeric and inorganic coatings, conversion coatings, metallic coatings, electrodeposition and electroless coatings. Hot dipping, (galvanizing, tinning, aluminizing, babitting, etc.)	**10**
Module 2	Paint coatings for corrosion protection, role of resins, pigment, additives and solvents. Application techniques: Surface preparation and its importance in coating, role of coating selection & design of coating, failure mechanism, maintenance coatings, industrial paint systems.	**10**
Module 3	Coatings for underground pipelines, storage tanks, overhead pipelines, offshore structures, ship hulls, risers, reinforced bars and concrete structures. Diffusion coatings, overlays, depositions, mechanical coatings.	**10**
Module 4	Functional Coatings: Coatings anti-biofouling, wear resistance, low-friction, erosion resistance, corrosion resistance, scratch resistance, primers, fatigue life improvements, thermal barrier coatings, Oxidation resistance, diffusion barrier coatings, environmental barrier coatings, optical coatings etc	**12**
	Total Hours	**42**

Books Recommended:

1. R. Lambourne and T.A. Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichster, 1987.
2. C.G. Munger, Corrosion Prevention by Protective Coatings, NACE Pub., Houston, 1984.
3. Surface Finishing, Cleaning & Coatings, ASM Handbook, Vol. 5, 1994.
4. J. Biesiek and J. Weber Portcullis, Electrolytic and Chemical Conversion Coatings, Red Hill Press, 1976.
5. F.A. Lowenheim, Electroplating: Fundamentals of Surface Finishing, McGraw-Hill, New York, 1978.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**(Honours elective 2) Electron Microscopy**	MMT 053	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Identify the working principles, instrumentation electron microscopy
CO2	Choose an appropriate electron microscopy technique for microstructural analysis
CO3	Analyze the microstructural features at high resolution
CO4	Recommend a suitable electron microscopic technique as per the requirement.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction:** Human eye, optical microscope, transmission electron microscope (TEM), scanning electron microscope (SEM), scanning transmission electron microscope (STEM), analytical electron microscopes, scanning-probe microscopes	**6**
Module 2	**TEM:** Electron gun, imaging system, theoretical limit, chromatic and spherical aberration, astigmatism, depth of field/focus, kinematics of scattering by atomic nuclei, electron-electron scattering, scattering contrast from amorphous and polycrystalline specimen, dark-field images, selected area diffraction technique, phase contrast, specimen preparation	**10**
Module 3	**TEM image contrast:** Inelastic and elastic electron scattering, Kikuchi patterns, absorption and phase contrast, diffraction contrast, dynamical theory and solution for perfect crystal, grain boundary fringes, stacking fault fringes, Moiré fringes, dislocations, small loops, vacancy aggregates, precipitates	**10**
Module 4	**SEM:** Operating principle, depth of field, noise, resolution, penetration of electrons into a solid, secondary-electron image, backscattered-electron image, other imaging modes, specimen preparation, environmental SEM, electron-beam lithography	**10**
Module 5	**Analytical electron microscopy**: The Bohr atom model, X-ray emission spectroscopy, X-ray energy-dispersive spectroscopy, quantitative analysis in the TEM and SEM, X-ray wavelength-dispersive spectroscopy, auger electron spectroscopy (AES), electron energy-loss spectroscopy (EELS)	**6**

Books Recommended:

1. Electron Microscopy and Analysis, P.J Goodhew J. Humphreys R Beanland, T&F, 2001.
2. Fundamentals of light microscopy and electronic imaging, Douglas B. Murphy, Wiley-Liss, Inc. USA, 2001.
3. Scanning Electron Microscopy and X-Ray Microanalysis: J. Goldstein and D. E. Newbury, Springer, 2011
4. Materials characterization, Yang Leng, JohnWiley & Son, 2008
5. Egerton, R., “Physical Principles of Electron Microscopy: An Introduction to TEM, SEM and AEM”, Springer. 2010
6. David B. Williams, C. Barry Carter, " Transmission Electron Microscopy: A Textbook for Materials Science" ,Springer, pub. 2009.
7. ASM Handbook, Volume 10, Materials Characterisation, Whan R E (Ed), ASM international,1986

Open Elective II
for
Non-MMED students

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Nanomaterials**	MMT 065	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Compare the properties of nanomaterials with regard to geometry and surface features.
CO2	Critique the selection process for synthesis of nanomaterials.
CO3	Interpret the fundamentals of mechanical, electrical and magnetic properties of the nanomaterial.
CO4	Evaluate the appropriate characterisation technique for different types of nanomaterials.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction to Nanomaterials:** Elementary Consequences of Small Particle Size, Nanoparticles, Diffusion Scaling Law, Surfaces in Nanomaterials, Surface Energy, 1D and 2D Nanoparticles, Nanostructures with Layered Structures, Carbon- and Boron-Nitride-Based Nanoparticles, Nanotubes, Nanorods, and Nanoplates from Materials other than Carbon, Synthesis of Nanotubes, Nanorods, and Fullerenes	**10**
Module 2	**Synthesis of Nanomaterials: Bottom Up and Top Down:** Gas Phase: Fundamental Considerations, Inert-Gas Condensation Process, Physical and Chemical Vapor Synthesis Processes. Severe Plastic Deformation Processes	**11**
Module 3	**Magnetic, Electrical and Mechanical Properties of Nanomaterials:** Fundamentals of Superparamagnetism, Susceptibility of Superparamagnetic Materials, Fundamentals of Electric Conductivity; Diffusive versus Ballistic Conductivity, Carbon Nanotubes, Electrical Conductivity of Nanocomposites, Mechanical Properties of Bulk Nanocrystalline Materials, Deformation Mechanisms of Nanocrystalline Materials, Superplasticity, Filled Polymer Composites, Carbon-Nanotube- and Graphene-Filled Composites	**10**
Module 4	**Characterisation of Nanomaterials:** Specific Surface Area, Analysis of Crystalline Structure, Electron Microscopy, Setup of Electron Microscopes, Interaction of the Electron Beam with the Specimen, Some Examples of TEM, High-Resolution SEM	**11**
	Total Hours	**42**

Books Recommended:

1. Poole C.P, and Owens F.J., Introduction to Nanotechnology, John Wiley, 2003
2. Nalwa H.S., Encyclopedia of Nanoscience and Nanotechnology, American Scientific Publishers, 2004
3. Koch C.C., Nanostructured Materials: Processing, Properties and Applications, W. Andrew, 2006
4. Zehetbauer M.J. and Zhu Y.T., Bulk Nanostructured Materials, Wiley, 2008
5. Wang Z.L., Characterization of Nanophase Materials, Wiley, 2000
6. Gutkin Y., Ovid'ko I.A. and Gutkin M., Plastic Deformation in Nanocrystalline Materials, Springer, 2004.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
3rd Year (6th Semester)	**Energy Materials**	MMT 066	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Interpret the working principles of modern devices for energy storage and conversion
CO2	Analyse the limitations, existing issues and wider aspect concerning commercialization of advanced devices
CO3	Interpret the basic principles of functioning of devices for electrochemical conversion and storage
CO4	Compare the physical-chemical mechanisms for the devices during their operation.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction:** Ragone charts, necessity of energy storage, specifications of energy storage devices, self-discharge time, unit size, efficiency, cycle life, specific energy, energy density.	**8**
Module 2	**Energy Storage Methods**: Mechanical energy storage, compressed air energy storage, flywheel storage, secondary battery storage, lead–acid battery, limitations of lead–acid storage batteries, sulfation, acid stratification, valve regulated lead acid battery, nickel–cadmium (Ni–Cd) battery, nickel–metal hydride (Ni–MH or Ni–MH) battery, lithium–ion battery (LIB), lithium–polymer battery, sodium–sulphur battery, ZEBRA battery, flow batteries, vanadium redox flow battery, polysulphide bromide battery, zinc bromide flow battery, supercapacitor.	**14**
Module 3	**Fuel Cells and Types:** Development stages and relative performances of various fuel cells, fuels for fuel cells, efficiency of a fuel cell, characteristics of fuel cell, fuel cell power plant, present status, environmental effects, phosphoric acid fuel Cell (PAFC), alkaline fuel Cell (AFC), polymer electrolyte membrane fuel cell (PEMFC), direct methanol fuel cell (DMFC), molten carbonate fuel cell (MCFC), solid oxide fuel cell (SOFC).	**12**
Module 4	**Hydrogen as Energy Carrier:** Properties of hydrogen, production, electrolysis of water, thermolysis of water, biophotolysis, storage, delivery, conversion.	**8**
	Total Hours	**42**

Books Recommended:

1. Non-Conventional Energy Resources/ B.H. Khan/ McGraw Hill Education (India) Private Limited/ 3rd edition. 2016
2. Electrochemical Energy Advanced Materials and Technologies/ Jiang, San Ping Shen, Pei Kang Sun, Xueliang Wang, Chao-Yang Zhang, Jiujun / Wiley-ISTE/ 1st edition., 2015

4th Year Syllabus

7th Semester

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**Metal Casting**	MMT 401	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Make use of foundry tools and design moulds for metal casting
CO2	Design gating elements for efficient casting processes of different metals and alloys.
CO3	Identify the different melting practices for different metals and alloys and also categorize different casting processes.
CO4	Inspect and assess the casting for the desired application.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction to metal casting:** Introduction, advantages, disadvantages and applications; classification of foundries. Types of moulding sands and their sources in India. Classification on the basis of grain size and distribution, shape, Testing of moulding sand, Ingredients of moulding sand and their effect on properties, binders and additives, machines for moulding sand preparation.	**6**
Module 2	**Mould, Core and Pattern Making:** Sand moulding process and its types, CO_2 process, shell and machine moulding, floor and pit moulding, vacuum, ceramic and permanent molding etc. Types of cores, core sands, preparation of cores, core baking and finishing, core allowances and core print design, Pattern making & material, functions of patterns and its types, Pattern allowances.	**10**
Module 3	**Gating and feeding:** Overview of pouring and solidification, concept of shrinkage, Functions of gating system and its various components, types of gates; functions of risers, types of riser, Chvorinov's rule, methods of designing proper gating and risering system for ferrous and non-ferrous casting, directional solidification and methods to achieve directional solidification.	**8**
Module 4	**Different Types of Casting Processes:** Various types of melting furnaces used in foundry; melting practice for steels, cast iron and its types, aluminium alloys, copper alloys and magnesium alloys, Classification of casting methods and equipment- sand casting, die casting, permanent mould casting, centrifugal casting, plaster mould casting, investment casting, continuous casting, squeeze casting, full mould process, strip casting, Rheo and thixocasting.	**10**
Module 5	**Heat treatment, casting defect, and Fettling:** Common casting defects - classifications, causes and remedies; salvaging and heat treatment of castings, shot blasting, grinding and fettling.	**8**
	Total Hours	**42**

Books Recommended:

1. Principles of Metal Casting, Heine R W., Loper, C.R. Rosenthal, Tata-McGraw Hill Publishing Co Ltd., 1995.
2. Principles of Foundry Technology, Jain P.L, Tata McGraw Hill, 1995
3. Metal Casting : Principles and Practice, R Rao T V., New Age International Publishing, 1996
4. Fundamentals of metal casting technology, Mukherjee P.C.,Oxford and IBH Publishing House, 1996
5. Manufacturing technology, Rao P N, Tata-McGraw Hill Publishing Co Ltd., 1998
6. ASM Metals hand Book, Vol 15, Casting, ASM International, 2001
7. Foundry Technology, Beeley P R., Butterworths, London, 1982
8. Foundry Engineering, Srinivasan N K., Khanna Tech Publications,1994

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**Polymer Technology**	MMT402	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Course Outcomes: After completing the course, the student should be able-

CO1	To apply the concepts of chemistry, structure, synthesis and properties of polymers
CO2	To analyze the concepts of chemistry, structure, synthesis and properties of polymers
CO3	To appraise the concepts of chemistry, structure, synthesis and properties of polymers

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Genesis, Chemistry of polymerization, Molecular weight and size, Kinetics of polymerization, chemical and geometrical structure,	**14**
Module 2	Glass transition temperature, crystallinity in polymers, copolymerization, individual polymers, polymer degradation,	**14**
Module 3	Polymer reactions, polymer solutions, elastomeric, fiber forming and plastic materials, polymer processing	**14**
	Total Hours	**42**

Recommended Books:

1. Polymer Science by Gowariker, Viswnathan, Jayadev Sreedhar, New Age International Ltd., 2005
2. Foundations of Materials Science and Engineering by William F.Smith, McGraw-Hill Inc, New York, 1997
3. Plastics: Materials and processing by Brent Strong A, Pearson; 3rd edition, 2005
4. Polymer Processing by Morton-Jones D.H, Chapman and Hall, New York, 2000

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**Laboratory Practice in Metal Casting**	MML 409	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60 Marks		40 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze the sand morphology and the effect of sand particle size distribution on the sand mold properties.
CO2	Illustrate different sand testing methods available for sand mold preparations.
CO3	Apply the mold and pattern preparation techniques to design proper gating system to achieve defect free casting.
CO4	Apply the different furnace melting technique to perform the casting of different alloys

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	1. To find the distribution of sand grains using a set of sieves and to find the average grain fineness number. 2. To determine the percentage of clay present in base sand. 3. To find the effect of water content, clay content on green permeability of foundry sand.	**8**
Module 2	4. To find the green compression strength of the given specimen at different percentage of clay and moisture 5. To determine the green shear strength of the given specimen for different percentages of clay and moisture. 6. To determine the tensile strength of sand using two types of binders Viz. core oil binder and sodium silicate binder.	**8**
Module 3	7. To determine the hardness of sand core and sand mould by using a steel ball tester. 8. Preparation of green sand mould. 9. To determine the flowability of moulding sand.	**6**
Module 4	10. Demonstration of foundry melting practice of ferrous and non-ferrous alloys. 11. To analyze the different types of defects in the casting product.	**6**
	Total Hours	**28**

Year(Semester)	Course Title	Course Code	L- T- P-Credits
4th year (7th Semester)	**Laboratory Practice in Polymer Technology**	MML 410	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60 Marks		**40 Marks**

Pre-requisites: None

Course Outcomes: At the end of the course, the student will be able to

CO1	Apply the techniques used to synthesise Resins and polymers
CO2	Analyze the various properties of synthesized polymers
CO3	Appraise the data, process parameters within realistic constraints of the experiment

Detailed Syllabus

Module No.	Contents	Hours
Module 1	1. Determination of molecular mass of styrene by viscosity measurements. 2. Study the effect of temperature on the viscosity of polymer solutions. 3. Determination of glass transition temperature by DSC method.	**8**
Module 2	4. Synthesis of Nylon 66 by interfacial polymerization and confirm the synthesis by IR spectroscopy. 5. Synthesis and kinetic investigation of radical polymerisation of styrene to polystyrene. 6. Synthesis of Melamine-Formaldehyde resin.	**8**
Module 3	7. Synthesis of a conducting polymer poly-aniline/polystyrene and determine its conductivity. 8. To determine Iodine value in the polymer sample. 9. To determine acid value in the polymer sample.	**8**
Module 4	10.To determine the melting range and softening range of polymers like Polyolefins 11. Determine the chlorine content of the chlorinated polymers	**4**
	Total Hours	**28**

Recommended books

1. A Laboratory Manual of Polymers: Volume I, 2013, by S. M. Ashraf (Author), Sharif Ahmad (Author), Ufana Riaz (Author); I K International Publishing House Pvt. Ltd
2. Practicals in Polymer Science–2007; Siddaramiah; CBS
3. Polymer Chemistry: A Practical Approach (The Practical Approach in Chemistry Series) 1st Edition Fred J. Davis Oxford University Press 2004
4. A Practical Course in Polymer Chemistry S. H. Pinner, Borough Polytechnic, London, Pergamon Press, New York, 1961

Year(Semester)	Course Title	Course Code	L- T- P-Credits
4th year (7th Semester)	**Project Preliminary work**	MMP 411	0-0-2-2
Evaluation Policy	**Supervisor**	**Project Evaluation Committee**	
	40 %	Mid Term evaluation 20%	End Term Evaluation 40%

Course Outcomes: At the end of the course, the student will be able to

CO1	Identify inconsistencies, gaps in research, conflicts in previous studies, open questions left from other research
CO2	Determine the research objectives and methodology to address the research gap

Details:

1. Each student will undertake a project work, involving complete literature survey, design and fabrication of some working process models, and /or a laboratory experimentation, and presentation of results, under the supervision of a faculty member to be fixed in a meeting of the faculty members of the department keeping in view the students choice of project topic, their aptitude, facilities available and the availability of staff.
2. The project will be assigned before the conclusion of the 6th semester examination and students will start working on literature survey etc., when 7th semester classes commence. A write-up and a complete list of consumables and non-consumable items to be needed by each student to complete the project work will be submitted to the teacher concerned in a fairly typed form for assessment and for arranging the materials from the market, if necessary, so that the practical work is started just at the commencement of the 8th semester classes. Each student will submit a complete literature survey of the project work assigned to the concerned supervisor for assessment.

Professional Elective

III, IV and V

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**(Professional Elective 3) Composite Materials**	MMT 005	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze various types of composites and their manufacturing techniques
CO2	Explain the dependence of the composite properties on the characteristics, relative amounts, geometry/distribution of the constituent phases
CO3	Evaluate the properties of non-conventional composites

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Introduction - Composites, Reinforcements and matrices, Types of reinforcements, Types of matrices, Types of composites, Properties of composites, Applications of metal, ceramic and polymer matrix composites.	**10**
Module 2	Manufacturing methods - Hand and spray lay - up, injection molding, resin injection, filament winding, pultrusion, centrifugal casting and prepregs. Characterization of systems; carbon fibre/epoxy, glass fibre/polyester, etc.	**12**
Module 3	Mechanical Properties - Geometrical aspects – volume and weight fraction. Unidirectional continuous fibre, discontinuous fibers, Short fiber systems – Mechanical Testing: Determination of stiffness and strengths of unidirectional composites. Structural Composites – Laminar Composites, Sandwich Panels	**20**
	Total Hours	**42**

Books Recommended:

1. Composite Materials by Chawla K K, Springer Verlag, New York, 1998
2. Composite Materials: Engineering & Science by Mathews F L and Rawlings R D, Chapman & Hall, London, 1994
3. Ceramic Matrix Composites by Chawla K K, Chapman and Hall, UK, 1993
4. Modern Composite Material by Broutman L J, and Krock, Addison Wesley Publishing Company, 1997
5. Composite Materials: Science and Applications by Deborah Chung D, Springer International, USA, 2004
6. "Composites" Metals Hand Book Vol.21, 9th Edition, ASM, 1989

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**(Professional Elective 3) High Temperature Materials**	MMT 006	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.
Course Outcomes: At the end of the course, the student will be able to:

CO1	Relate the microstructure control and the required high temperature properties of materials
CO2	Categorize different materials based on the high temperature properties and applications
CO3	Select the materials and coatings for specific application
CO4	Evaluate the life of high temperature materials by applying Larson Miller approach for reliable design of structures

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction:** Need for high temperature materials, historical development of high temperature materials, Requirements of high temperature materials: Gas turbine engine, Selection of materials for high temperature.	**4**
Module 2	**Failure Mechanisms at high temperature:** Oxidation and Deformation phenomenon. Oxidation and types, Mechanism of oxidation, Hot Corrosion and classification. Creep and stress rupture, structural changes during creep, mechanism of creep deformation, and fracture at elevated temperatures. Larson –Miller Parameter, Creep-Fatigue interaction, fatigue-creep interaction, micro-mechanism of damage, creep-fatigue testing, influence of environment.	**10**
Module 3	**Materials for high temperature**: **Metals/alloys:** steels, titanium and its alloys, Superalloys, Classification of superalloys, Physical Metallurgy of Nickel-based superalloy defects and strengthening mechanism.	**12**
Module 4	**Materials for high temperature-Ceramics:** (Alumina, Zirconia, Silicon carbide, Silicon nitride, Glass ceramics) composites (Metal matrix composites, ceramic matrix composites) carbon–carbon composites. Principles for high temperature strengthening of Ceramics and composites.	**10**
Module 5	**Coatings for protection against high temperature corrosion and erosion:** Corrosion/oxidation resistant coatings (metallic, ceramic, rare and reactive metal reinforced coatings), high temperature erosion and wear, thermal barrier coatings. Failure of thermal barrier coatings.	**6**
	Total Hours	**42**

Books Recommended:

1. Meetham, G. W., Van de Voorde, M. H., "Materials for High Temperature Engineering Applications (Engineering Materials)", 1st Ed., Springer. 2000
2. Chan R. W., "High temperature structural materials", Chapman & Hall.1996
3. Reed R. C., "The Super-alloys: Fundamentals and Applications" Cambridge University Press. 2008
4. Birks, N., Meier, G. H., and Pettit, F. S., "Introduction to the High Temperature Oxidation of Metals", Cambridge University Press. 2009
5. Bose, S., "High Temperature Coatings", Butterworth-Heinemann. 2007

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**(Professional Elective 4) Selection and Properties of Materials**	MMT 007	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Justify and select the materials required for mechanical design.
CO2	Assess the material properties and materials fabrication processes and an approach for process selection to design a process
CO3	Analyse multiple constraints and conflicting objectives for selection of materials
CO4	Designing new materials and conceiving hybrid solutions for required applications.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction:** Historical evolution of engineering materials Engineering materials and their properties- atomic bonding, elasticity, stress, strain, families of engineering materials, materials information for design	4
Module 2	**Materials property chart:** exploring materials properties, materials property charts e.g. the modulus- density chart, the strength-density chart, the fracture toughness-modulus chart, thermal conductivity-electrical resistivity chart	**9**
Module 3	**Materials selection:** the selection strategy, materials indices, the selection procedure, Multiple constraints and conflicting objectives: selection with multiple constraints, conflicting objectives, Ashby Material Selection Chart	**8**
Module 4	**Selection of materials and shape:** shape factors, limits to shape efficiency, exploring the materials shape combinations, materials indices that include shape, architectured materials	**8**
Module 5	**Processes and process selection:** classification of processes: shaping, joining and finishing, processing for properties, process selection, ranking process cost	**5**
Module 6	**Designing hybrid materials:** holes in materials property space, composites, sandwich structures, cellular structures, segmented structures, case studies.	**8**
	Total Hours	**42**

Books Recommended:

1. Materials- Engineering, Science, Processing and Design, M. Ashby, H. Shercliff, David Cebon, Elsevier, 2008
2. Engineering Materials: Properties and Selection, Budinski, Kenneth G. and Budinski, Michael K., Pearson Prentice Hall, 2010
3. Materials Selection in Mechanical Design, Michael F. Ashby, Butterworth-Heinemann, 2011.
4. Engineering Materials 2 - An Introduction to Microstructures and Processing, M.F. Ashby, DRF Jones, Elsevier, 2013.
5. Mechanical Metallurgy, Dieter G. E., Mc Graw Hill, 2013.
6. Mechanical Behavior of Materials, T.H. Courtney, McGraw Hills, 1990.
7. Physical Metallurgy Principles, Robert E. Reed-Hill, Affiliated E-W Press Pvt. Ltd., 2008.

Year (Semester)	Course Title	Course Code	L- T- P-Credits
4th year (7th Semester)	**(Professional Elective 4) Tribology of Engineering Materials**	MMT 008	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: Nil

Course Outcomes: At the end of the course, the student will be able to

CO1	Analyze the significance of tribology in metallurgical systems
CO2	Characterize the solid surfaces
CO3	Analyze and measure friction between various types of materials.
CO4	Analyze, measure and mitigate wear of engineering materials.

Detailed Syllabus

Module No.	Contents	Hours
Module 1	**Introduction to tribology:** Defining tribology, Industrial significance of tribology, Nature of metallic surface, physicochemical characteristics of surface layers, quantifying surface roughness, Friction, the laws of friction, measurement of friction, origin of friction, theories of friction. Friction of metals and alloys, ceramics and polymers.	**10**
Module 2	**Wear:** Types of wear, Archard's law, abrasive wear, erosion wear, factors affecting corrosive wear, fretting and fretting corrosion, types of particles present in wear debris, wear map, wear of metals and alloys, ceramics and polymers, various wear testing methods- pin on disc, pin on drum, slurry wear, air jet and water jet erosion as per ASTM standards.	**16**
Module 3	**Tribological properties of solid materials**: Hardness, strength, ductility and work hardening rate, effect of crystal structure, effect of microstructure, mutual solubility of rubbing pairs and effect of temperature. Surface treatments to reduce wear: Surface treatments with or without change of composition, surface coating-welding, flame, spraying, plasma spraying, electroplating and electroless coating, chemical vapour deposition (CVD) and physical vapour deposition (PVD), super hard coatings.	**16**
	Total Hours	**42**

Recommended Books

1. Bhushan B., Introduction to Tribology, John Wiley R2002
2. Bhushan B., Principles and Applications of Tribology, John Wiley 1999

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**(Professional Elective 5)** **Science and Technology of Thin Films**	MMT 009	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Illustrate the scientific principles of processing of thin films
CO2	Evaluate and use models for nucleating and growth of thin films
CO3	Assess the relation between deposition technique, film structure, and film properties
CO4	Characterize the film and discuss typical thin film applications

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Vacuum systems components: Dry and vapour pumps, pressure measurement gauges, conductance and other system design considerations. Thin film deposition techniques: Physical and chemical vapour deposition techniques including molecular beam epitaxy, laser ablation and hot wire and microwave CVD techniques.	**20**
Module 2	Growth of thin films: Thermodynamic and kinetic considerations of deposition of thin films by both CVD and PVD. In situ characterization of thin film deposition process.	**10**
Module 3	Characterization of thin films: Different methods of thickness measurements, electrical, optical, chemical and structural property determination. Applications: Some important applications of thin films: Hard and decorative coatings, semiconductor thin films, organic thin films.	**12**
	Total Hours	**42**

Books Recommended:

1. Ohring, M., "Materials Science of Thin Films", 2nd Ed., Academic Press.
2. Smith D.L., "Thin-Film Deposition: Principles and Practice", McGraw-Hill Professional.
3. Kagan, C.R., Andry, P., "Thin Film Transistors", Marcel Dekker.
4. Eishabini-Riad, A., Barlow, F. D., "Thin Film Technology Handbook", 1st Ed., McGraw-Hill Professional.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**(Professional Elective 5) Thermo-mechanical Processing**	MMT 010	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: Physical Metallurgy, Mechanical Metallurgy
Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply the deformation and heat treatment process to optimize the properties of metallic materials
CO2	Analyze the effect of processing parameters on the microstructure and mechanical properties of metallic materials
CO3	Evaluate the effect of different processing techniques on the development of microstructure in materials.
CO4	Modify the microstructure of materials by applying suitable deformation and annealing methods.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction to Thermomechanical Processing**: Microstructure and Properties, Classification of forming processes, concept of dislocations and dislocation structures, slip and twinning, Deformation in polycrystals, flow curves, Work Hardening, Textural developments during thermomechanical processing, Deformation and Recrystallization texture (FCC, BCC); hot deformation; Deformation mechanism maps.	**18**
Module 2	**Softening mechanisms:** Recovery - mechanism and kinetics, structural changes during recovery. Dislocation migration and annihilation, polygonization, subgrain formation; Recrystallization - mechanism and kinetics, JMAK model. Particle stimulated nucleation; Grain growth – mechanism and kinetics. Abnormal grain growth; static and dynamic recrystallization,	**12**
Module 3	**Case studies:** Thermomechanical processing based on Severe plastic deformation, thermomechanical processing of aluminum, steels and other important metallic materials.	**12**
	Total Hours	**42**

Books Recommended:

1. Thermomechanical Processing of Metallic Materials: B. Verlinden, J. Driver, I. Samajdar and R.D. Doherty, Pergamon Materials Science, Elsevier, 2007.
2. Metal forming: Mechanics and Metallurgy: W.F. Hosford and R.M. Caddell, 4th Ed., Cambridge University Press, 2014.
3. Recrystallization and Related Annealing Phenomena, F.J. Humphreys and M. Hatherly, 2nd Eds, Elsevier, 2004.
4. Introduction to Physical Metallurgy, S. Avner, Tata Mc Graw Hill, 2008
5. Principles of Physical Metallurgy, Reed Hill, CT: Cengage Learning, 2008

Honours Elective
III and IV

Year (Semester)	Course Title	Course Code	L- T- P-Credits
4th year (7th Semester)	**(Honours elective 3)** **Additive Manufacturing**	MMT 011	2-1-0-3
Evaluation Policy	**Mid-Term**	**Class Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: Nil

Course Outcomes: At the end of the course, the student will be able to

CO1	Evaluate the metallurgical and materials engineering aspects of additive manufacturing.
CO2	Analyze the additive manufacturing process physics to design and fabricate the 3D parts with desired structure and property.
CO3	Monitor and control the additive manufacturing (AM) process.
CO4	Perform suitable post processing operation based on product repair requirement.

Detailed syllabus

Module No.	Contents	Hours
Module 1	**Additive Manufacturing Overview:** Direct Digital Manufacturing and their importance. Different AM processes and relevant Process Physics. Applications of Additive Manufacturing: Additive Manufacturing in Aerospace, Automotive, Electronics industries and Biomedical applications.	**14**
Module 2	**AM Powder Production and Characterization:** Different Mechanical and Chemical methods, Atomization of Powder, other emerging processes. Performance Evaluation of different processes. Chemical and Microstructural Characterization of powders. Metallurgical Aspects of AM process: Solidification. Texture. Non-equilibrium Microstructure. Residual stress. Process-Structure-Property relationship.	**15**
Module 3	**Process monitoring and Control for AM:** Defects, Geometry, Temperature, Composition and Phase Transformation. Post processing of AM parts; Support material removal. Machining. Heat Treatment. Hot Isostatic Processing. Hybrid manufacturing	**13**
	Total Hours	**42**

Books Recommended

1. Gibson I., David W. R., Stucker B., Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Springer, 2nd Ed. (2015).

2. Chua C.K., Leong K.F. and Lim C.S., Rapid prototyping: Principles and applications, 3rd Edition, World Scientific, 20

Year (Semester)	Course Title	Course Code	L- T- P-Credits
4th year (7th Semester)	**(Honours elective 3)** **Creep, Fatigue and Fracture**	MMT 012	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None

Course outcomes: At the end of the course, the student will be able

CO1	Contrast and compare different failure modes of materials
CO2	Evaluate creep behaviour of materials.
CO3	Apply various methods to improve fatigue strength of materials and estimate component life.
CO4	Evaluate basic fracture modes and analyze structural integrity.

Detailed Syllabus

Module No.	Contents	Hours
Module 1	**Creep behaviour of metals:** Creep; stress-time-temperature relations, creep testing methods. Mechanics of creep in tension, bending and torsion. Strain-hardening effects on creep. Creep buckling, members subjected to combined stresses and creep.	**10**
Module 2	**Fatigue:** Repeated stresses and fatigue in metals: Fatigue tests, endurance limit. Fatigue under combined loadings. Fatigue design theory: Goodman, Gerber and Soderberg criteria. Factors influencing fatigue behavior of metals: Frequency, temperature, size, form, surface conditions, residual stress, etc. Influence of stress concentration, Notch sensitivity. Various mechanical and metallurgical methods used for improving fatigue strength of metals. Effect of corrosion, Corrosion fatigue and fretting. Cumulative fatigue damage and life estimation of components.	**16**
Module 3	**Fracture mechanics:** Basic modes of fracture. Griffith theory of brittle fracture and Orwon’s modifications. Linear Elastic fracture mechanics: Stress field ahead of crack-tip, Stress Intensity factors, Critical SIF, Fracture toughness testing and evaluation of KIC. Elasto-plastic fracture mechanics: Plane stress and plane strain plastic zone sizes. J-Integral method. SERR computations and evaluation of structural integrity.	**16**
	Total Hours	**42**

Books Recommended

1. Engineering Fracture Mechanics S. A. Meguid (Springer)
2. Elementary Engineering Fracture Mechanics David Broek (Springer)
3. Fracture Mechanics C. T. Sun and Z. H. Jin (Elsevier)
4. Elements of Fracture Mechanics Prashant Kumar (Tata Mcgraw Hill)

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**(Honours elective 4) Nanomaterials**	MMT 013	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Compare the properties of nanomaterials with regard to geometry and surface features.
CO2	Critique the selection process for synthesis of nanomaterials.
CO3	Interpret the fundamentals of mechanical, electrical and magnetic properties of the nanomaterial.
CO4	Evaluate the appropriate characterisation technique for different types of nanomaterials.

Detailed Syllabus:

Module No.	Contents	hours
Module 1	**Introduction to Nanomaterials** Elementary Consequences of Small Particle Size, Nanoparticles, Diffusion Scaling Law, Surfaces in Nanomaterials, Surface Energy, One- and Two-Dimensional Nanoparticles, Nanostructures Related to Compounds with Layered Structures, Carbon- and Boron-Nitride-Based Nanoparticles, Nanotubes, Nanorods, and Nanoplates from Materials other than Carbon, Synthesis of Nanotubes, Nanorods, and Fullerenes	**10**
Module 2	**Synthesis of Nanomaterials: Bottom Up and Top Down** Gas Phase: Fundamental Considerations, Inert-Gas Condensation Process, Physical and Chemical Vapor Synthesis Processes. Severe Plastic Deformation Processes	**10**
Module 3	**Magnetic, Electrical and Mechanical Properties of Nanomaterials** Fundamentals of Superparamagnetism, Susceptibility of Superparamagnetic Materials, Fundamentals of Electric Conductivity; Diffusive versus Ballistic Conductivity, Carbon Nanotubes, Electrical Conductivity of Nanocomposites, Mechanical Properties of Bulk Nanocrystalline Materials, Deformation Mechanisms of Nanocrystalline Materials, Superplasticity, Filled Polymer Composites, Carbon-Nanotube- and Graphene-Filled Composites	**12**
Module 4	**Characterisation of Nanomaterials** Specific Surface Area, Analysis of the Crystalline Structure, Electron Microscopy, Setup of Electron Microscopes, Interaction of the Electron Beam with the Specimen, Some Examples of Transmission Electron Microscopy, High-Resolution Scanning Electron Microscopy	**10**
	Total Hours	**42**

Books Recommended:

1. Poole C.P, and Owens F.J., Introduction to Nanotechnology, John Wiley, 2003
2. Nalwa H.S., Encyclopedia of Nanoscience and Nanotechnology, American Scientific Publishers , 2004
3. Koch C.C., Nanostructured Materials: Processing, Properties and Applications, 2006
4. Zehetbauer M.J. and Zhu Y.T., Bulk Nanostructured Materials, Wiley, 2008
5. Wang Z.L., Characterization of Nanophase Materials, Wiley, 2000
6. Gutkin Y., Ovid'ko I.A. and Gutkin M., Plastic Deformation in Nanocrystalline Materials, Springer , 2004
7. Fischer A.C., Nanoindentation, Springer, 2002

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**(Honours elective 4) Fundamentals of Electro-Chemistry**	MMT 014	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply fundamental principles of electrochemistry, including thermodynamics, electrode-solution interface, electric charge, conductance, and electrochemical kinetics, to derive the Nernst equation and understand cell EMF and sign conventions.
CO2	Apply theoretical concepts electrochemical kinetics, current-potential relationship, Butler-Volmer equation, Tafel equation, reaction mechanisms, mass-transfer effects, Nernst law in practical applications.
CO3	Analyze the methodology involving potential measurements, cyclic voltammetry, Tafel analysis, linear polarization technique, electrochemical impedance spectroscopy, assessing their efficiency and appropriateness for specific experimental objectives.
CO4	Utilize electrochemistry in electron-transfer theory, electrocatalysis, bioelectrochemistry, photo-electrochemistry, corrosion, electroplating, and batteries for various applications.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Fundamental principles of electrochemistry:** Thermodynamics, Electrode-solution interface and double-layer structure, Electric charge, charges at rest, capacitance and conductance, Mobilities, Electrical circuits, Electrochemical kinetics, Derivation of Nernst equation, Cell EMF, Sign conventions, Electrochemical series, Reference electrodes, Standard potentials, and Nernst equation vs. open circuit potential	**10**
Module 2	**Theoretical basis for methods:** Chemical/electrochemical kinetics, current-potential relationship, exchange current, Butler-Volmer equation, Tafel equation and plots, reaction mechanisms, Mass-transfer effects, Nernst approximation coupled reactions and corrosion. Effect of temperature and concentration, ionic mobility and ionic conductance, Kohlrausch's law and its applications.	**10**
Module 3	**Methodology:** Potential measurements, cyclic voltammetry, Tafel analysis, linear polarization technique, chronoamperometry, chronocoulometry, rotating disk and rotating ring disc electrodes, ultra microelectrodes, electrochemical impedance spectroscopy, applications of conductivity measurements, concentration cells with, liquid junction potential. Theory of strong electrolytes and Debye Huckel Onsager theory, verification of Onsager equation, Wein effect and Debye–Falkenhagen effect, ionic strength, activity and activity coefficients of strong electrolytes.	**10**
Module 4	**Electrochemical instrumentation:** Voltmeters, ammeters, Potentiostats, Galvanostats, IR compensation, Design of electrochemical cells	**6**
Module 5	**Application of electrochemistry:** Electron-transfer theory, Electrocatalysis, Bioelectrochemistry, Photo- electrochemistry, Corrosion, Electroplating, and Batteries.	**6**
	Total Hours	**42**

Books Recommended:

1. An Introduction to electrochemistry / S Glasstone / Maurice Press/10th edition 2011
2. Electrochemical Methods: Fundamentals and Applications / Allen J Bard, Larry R Faulkner / Wiley/2nd edition 2000

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (7th Semester)	**(Honours elective 4) Severe Plastic Deformation**	MMT 015	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Compare severe plastic deformation methods from several viewpoints, including processing and final property
CO2	Apply ultrafine-grained and nano-grained metals and methods for various bulk, sheet, tubular and large size samples
CO3	Classify severe plastic deformation methods based on the sample shape and mechanics, as well as the properties achieved in the processed metal
CO4	Analyze effective parameters for the success of severe plastic deformation methods

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Fundamentals of Severe Plastic Deformation:** Basic principles, grain refinement mechanisms, difference between conventional and severe plastic deformation processes	**10**
Module 2	**Severe Plastic Deformation for Bulk Samples:** High Pressure Torsion, Equal Channel Angular Pressing, Dual Equal Channel Lateral Extrusion, Channel Angular Pressing with Converging Billets, Nonequal Channel Angular Pressing, Torsion Extrusion, Multiple Direct Extrusion, Accumulated Extrusion, Pure Shear Extrusion, Equal Channel Forward Extrusion, Multidirectional forging, Multiaxial Incremental Forging and Shearing, Repetitive Forging, Repetitive Upsetting, cyclic extrusion.	**12**
Module 3	**Severe Plastic Deformation for Sheets:** Accumulative Roll Bonding, Cone-Cone Method, Constrained Groove Pressing, Friction Stir Processing, Equal Channel Angular Rolling, Repetitive Corrugation, Asymmetric Rolling.	**10**
Module 4	Effective parameters for the success of severe plastic deformation methods, Mechanical properties of UFG and NS metals, Physical and chemical properties of UFG and NS metals, Applications of UFG and NS metals	**10**
	Total Hours	**42**

Books Recommended:

1. Severe Plastic Deformation Methods, Processing and Properties 1st Edition - July 14, 2018, Authors: Ghader Faraji, H.S. Kim, Hessam Torabzadeh Kashi, Elsevier
2. Severe Plastic Deformation Technology, Whittles Publishing Limited, Editor Andrzej Rosochowski, ISBN:9781849950916, 1849950911, 2017.
3. Nanomaterials by Severe Plastic Deformation, Editors:Michael J. Zehetbauer, Ruslan Z. Valiev, Publisher:Wiley, 2006, ISBN:9783527604944

8^{th} Semester

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (8th Semester)	**Non-Destructive Testing and Evaluation**	MMT 451	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply NDT Techniques in quality control of various manufacturing units and basics of NDT
CO2	Distinguish the principles, procedure and equipment for various methods of NDT.
CO3	Select suitable NDT method based on their reliability, accuracy and cost
CO4	Assess the data for the prediction of defect in different industry and manufacturing units

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Introduction and importance of NDT testing in the quality control of materials/product, Scope and limitations of NDT, Career prospects in NDT. Classification of NDT methods. Visual examination methods.	**4**
Module 2	**Liquid Penetrant Testing (LPT) –** Principle and procedure for defect inspection using LPT. Types and properties of liquid penetrants and developer. Advantages, disadvantages and applications of LPT. **Magnetic Particle Inspection (MPI)-** Principle and procedure of MPI. Advantages, disadvantages and applications of MPI. **Ultrasonic Testing (UT):** Basic principle and procedure for defect inspection using UT. Instruments. Advantages, disadvantages and applications of UT.	**14**
Module 3	**Acoustic Emission Testing (AET**)- Basic principle and procedure of AET. Characteristics of A.E signals. Kaiser and Felicity effect. Advantages, disadvantages and applications	**6**
Module 4	**Eddy Current Testing (ECT)-**Basic principle of working. Procedure for defect identification. Types of Eddy current probes. Advantages, disadvantages and applications of ECT. **Radiography Testing (RT)-** Basic principle of RT and procedure. Radiography film: properties, processing techniques and evaluation. Advantages, disadvantages and applications of RT.	**12**
Module 5	**Thermography and Holography-** Basic principle and procedure of thermography and holography. Defect analysis. Advantages, disadvantages and application of thermography and holography. **In-situ Metallographic Examination:** Analysis of defects present on material surface by optical microscopy. Selection of NDT methods.	**6**
	Total Hours	**42**

Books Recommended:

1. Non-Destructive Evaluation and Quality Control, ASM Metals Handbook, American Society of Metals, Metals Park, Ohio, 2001
2. Non-Destructive Testing, MC, Gonnagle, W T, McGraw Hill Book Co, 1988
3. Non-Destructive Testing, Louis Cartz, ASM International, Metals Park Ohio, 1995
4. Non-Destructive Testing, Barry Hull and Vernon John, ELBS / Macmillan, 1989

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (8th Semester)	**Laboratory Practice in Non-destructive Testing**	MML 456	0-0-2-1
Evaluation Policy	**Continuous Assessment**		**End-Term**
	60		40

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Examine the defects using Liquid penetrant testing and Magnetic particle testing
CO2	Select the appropriate non-destructive testing method for surface and sub-surface defects
CO3	Evaluate the defects, thickness of coatings and conductivity using the Eddy-current testing
CO4	Interpret the plots obtained from ultrasonic testing

Detailed Syllabus:

Module No.	Contents	Hours
1	1. To identify various surface weld defects by visual inspection. 2. To identify surface defects in castings by visual inspection. 3. To identify/detect discontinuities on a given sample using Ultrasonic Inspection.	**7**
2	4. Surface preparation of the sample for Liquid Penetrant Testing (Pre cleaning) 5. To apply the penetrant and developer 6. Examination and interpretation of the defects 7. To perform post cleaning of the test specimens	**7**
3	8. To perform demagnetization of test specimen 9. To detect flaws in magnetic materials using Magnetic Particle Inspection 10. Identification and Inspection of the flaws 11. Post-cleaning of the surface by removal of magnetic particles	**7**
4	12. To study the surface and near surface defects of conductive material using eddy current. 13. Analysis of the curves obtained on oscilloscope 14. Interpretation and comparison of the plots	**7**
	Total Hours	**28**

<table>
<tr><th>Year (Semester)</th><th colspan="2">Course Title</th><th>Course Code</th><th colspan="2">L-T-P-Credits</th></tr>
<tr><td>4th Year
(8th Semester)</td><td colspan="2">Major Project</td><td>MMP 457</td><td colspan="2">0-0-6-6</td></tr>
<tr><td rowspan="2">Evaluation Policy</td><td colspan="3">Supervisor</td><td colspan="2">Project Evaluation Committee</td></tr>
<tr><td colspan="3">40%</td><td>Mid term evaluation 20%</td><td>End term Evaluation 40%</td></tr>
</table>

Course Outcome:

CO1	The student should be able to perform an industrial **project** or applied research linked to the discipline of MME.
CO2	Interpret the research findings based on the work done in order to achieve the objectives
CO3	Draw conclusions on the basis of the findings
CO4	Propose future work

Details:

Final project report will be submitted by each student after making a presentation of his results/findings etc., before his/her supervisor and other faculty members. Final assessment of his/her project work will be done on the basis of a viva-voce examination by an external examiner.

Professional Elective VI and VII

Year (Semester)	Course Title	Code:	L-T-P-Credits
4th Year (8th Semester)	**(Professional Elective 6)** **Failure Analysis**	MMT 054	**2-1-0-3**
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End - Term**
	26 Marks	24 Marks	50 Marks

Course Outcomes:

CO1:	Analyze the mechanics of the various failure modes- Fracture, Fatigue, Creep and corrosion
CO2:	Generalize the broad spectrum of possibilities or reasons of the failure that may be employed to component or structure
CO3:	Analyze the failure process of the component or structure
CO4:	The design of a component or structure to minimize the possibilities of failure in service

Detailed Syllabus

Module Number	Contents	Hours
Module 1	**Failure:** Introduction **Fracture** Fundamentals of Fracture, Ductile Fracture, Brittle Fracture, Principles of Fracture Mechanics, Fracture Toughness Testing **Fatigue** Cyclic Stresses, The S–N Curve, Crack Initiation and Propagation Factors That Affect Fatigue Life, Environmental Effects **Creep** Generalized Creep Behavior, Stress and Temperature Effects, Data Extrapolation Methods, Alloys for High-Temperature Use	**18**
Module 2	Fundamental sources of failures.	**6**
Module 3	General practice in failure analysis.	**6**
Module 4	Service failures of cold formed parts, forgings, castings, weldments., failures in power plants.	**12**
	Total Hours	**42**

Recommended Books

1. Metallurgy of Failure Analysis, A.K.Das, Tata McGraw Hill Publishing Company Ltd New Delhi
2. Understanding How Components fail, by Donal J. Wulpi, second Edition.
3. Metals Hand book , 8th edition vol .10. Americal Society For Metals
4. Testing of Metallic Materials, Suryanarayana AVK, PHI,1

Year (Semester)	Course Title	Code:	L-T-P-Credits
4th Year (8th Semester)	**(Professional Elective 6)** **Alternative Methods of Iron Making**	MMT 055	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End - Term**
	26 Marks	24 Marks	50 Marks

Course Outcomes:

CO1	Elaborate the basic concepts of DRI, Smelting reduction process.
CO2	Compare the alternate methods of Iron Making based on their products obtained and their uses.
CO3	Analyze the DRI process based on their applications
CO4	Determine the present status and advancements so far in alternate methods of Iron Making in India.

Detailed Syllabus

Module Number	Contents	Hours
Module 1	Need for the development of alternative routes, approaches towards new techniques. Classification of processes. Raw materials used in alternate routes for iron making and their preparation. Thermodynamics and kinetics of iron oxide reduction. Heat and Material balance.	**15**
Module 2	Commercial processes for the production of direct reduced iron using shaft, kiln, retort and rotary hearth reactors. Concept of composite and pre-reduced pellet.	**10**
Module 3	Smelting-Reduction Processes: Principles, classification, merits and limitations. COREX, ROMELT, Hismelt, Fastmelt, Electro-thermal smelting etc.	**10**
Module 4	Storage, transportation, and utilization of sponge iron. Current status of Alternate methods of iron making and advancement so far in India and World.	**07**
	Total Hours	**42**

Recommended books:

1. Alternate routes of iron making by Amit Chatterjee, PHI.
2. Beyond blast furnace by Amit Chatterjee.
3. Sponge iron production in rotary Kiln by A. Sarangi and B. Sarangi, PHI.
4. Direct Reduction of Iron, Editors: Jerome Feinman & Donald R. Mac Rae, Allied Publishers Ltd.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (8th Semester)	**(Professional Elective 7)** **Introduction to Multicomponent & High Entropy Alloys**	MMT 056	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: Physical Metallurgy, Heat Treatment

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply the concept of materials thermodynamics and physical metallurgy to design the advanced structural materials.
CO2	Analyze the microstructure and its influence on the structural properties of multicomponent alloys
CO3	Evaluate the phase diagram to predict the phase formation in the complex compositional alloys
CO4	Make use of novel alloys to overcome the limitations in application of conventional alloys

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction**: Background of multicomponent alloys, Bulk metallic Glasses, High Entropy alloys, Core effects of HEAs, Physical metallurgy of HEAs, Alloy design strategy conventional vs HEAs. Design and analysis of HEAs using Thermocalc.	**15**
Module 2	**Microstructure and Processing:** Synthesis, processing and microstructure of different types of HEAs like Single phase HEAs, Refractory HEAs & Eutectics HEAs	**10**
Module 3	**Properties of HEAs**: Mechanical properties of FCC, BCC and multiphase high entropy alloys, wear properties, corrosion and oxidation behaviour of HEAs, application of HEAs.	**10**
Module 4	**Novel High Entropy materials and their properties**: High Entropy Ceramics: nitrides, carbides, oxides, composites.	**7**
	Total Hours	**42**

Text Books Recommended

1. B.S. Murty, Jien-Wei Yeh, S. Ranganathan, Pinaki P Bhattacharjee, High Entropy Alloys, 2nd Edition, Butterworth-Heinemann, 2019
2. High Entropy Alloys Fundamentals and Applications, M C Gao et al, Springer

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (8th Semester)	**(Professional Elective 7) Biomaterials**	MMT 057	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Illustrate and define biomaterials from a material-engineer's perspective
CO2	Classify biomaterials based on the material-type, structural application, and material-response
CO3	Discover Immune-response and drug delivery mechanisms
CO4	Interpret various cell/tissue/implant interactions based on case studies

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Introduction - Introduction to materials at the interface with biological sciences, Social, Environmental & Ethical Issue. Classification of biomaterials- a) Response Based: Bioinert/ Bioactive/ Bioresorbable b) Material Based: Bioceramic/ Biopolymer/ Biometallic c) Application Based: Structural (Bone replacement materials, dental biomaterials, cardiovascular biomaterials, total hip and knee replacement), Non-structural (drug-delivery/ sensing/ surface modification)	**12**
Module 2	Concept of biocompatibility: - Definition, Immune response, Testing (in vitro/ in vivo), Biological phenomenon on material surfaces, Principles of various surface Characterization techniques: Atomic force microscopy, fluorescence microscopy, tensiometer (contact angle measurement) etc.	**10**
Module 3	Processing and properties of biocompatible materials- Bioglass/ Glass-ceramics- Macroporous scaffolds - Biodegradable polymers - Biocomposites - Thin films and coatings	**12**
Module 4	Case Studies- Articulating joints - Dental restorative applications - Cardiovascular patches/ heart valves	**8**
	Total Hours	**42**

Books Recommended:

1. Park J.B. and Bronzino J.D., Biomaterials: Principles and Applications, CRC Press
2. Park J.B., Biomaterials Science and Engineering, Springer Press
3. Rattner B.D., Hoffman A.S, Schoen F.J., Lemons J.E., Biomaterials Science: An Introduction to Materials in Medicine, Academic Press
4. Park J.B. and Lakes R.S., Biomaterials: An Introduction, 3rd edition, Springer press
5. Bhat, S.V., Biomaterials, 2nd edition, Narosa Publishing

Honours Elective
(V, VI and VII)

Year (Semester)	Course Title	Code	L-T-P-Credits
4th Year (8th Semester)	**(Honours Elective 5) Secondary Steel Making**	MMT 058	2-0-0-2
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End - Term**
	26 Marks	24 Marks	50 Marks

Course Outcomes: At the end of the course, the student will be able to:

CO1	Explain the concept of clean steels – their characteristics and importance, fundamentals and practices of secondary steel making processes
CO2	Prove the need for continuous casting over other casting techniques.
CO3	Compare the secondary steel making decarburization techniques and compare the final products obtained.
CO4	Develop a clear understanding of the concept of clean steels-their characteristics and importance and to perform thermodynamic and kinetic calculations to real industrial problems.

Detailed Syllabus

Module Number	Contents	Hours
Module 1	The concept of cleanliness of steels, non-metallic inclusions, dissolved gases. Tramp & residual elements in steels and their effect on steel properties. Thermodynamic and kinetics consideration of deoxidation, desulphurization, decarburization and degassing of steel melts. Limitations of primary steel making, unit operations and unit processes in ladle metallurgy, slag free tapping. Ladle furnaces design and operation, injection metallurgy.	**10**
Module 2	Unit processes in secondary steel making like stirring treatment (with lances, bottom pouring plus, EMS) and its application to production of special and alloy steel. Furnaces and equipment's used in the secondary steel making process.	**07**
Module 3	Decarburisation techniques used (AOD, VOD), Fundamental and practical aspects of Injection Metallurgy (powder/wire), Post solidification treatments, Vacuum Degassing.	**07**
Module 4	Advanced features of Continuous Casting. Application of modelling and simulation in steel making. Understanding defects, recent developments in Refractories used in secondary steel making.	**04**
	Total Hours	**28**

Text books:

1. Introduction to modern steel making by R.H. Tupkary and V.R. Tupkary (2008)
2. Secondary steel making: Principles and Application Ahindra Ghosh ISBN-10:0849302641, ISBN-13: 978-1420062434
3. Iron and steel making: theory and practice Ahindra Ghosh, Amit Chatterjee.

Year(Semester)	Course Title	Course Code	L- T- P-Credits
4th year (8th Semester)	**(Honours Elective 5) Smart materials**	MMT 059	2-0-0-2
Evaluation Policy	**Mid-Term**	**Class Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: Nil

Course Outcomes: At the end of the course, the student will be able to

CO1	Discover the basic principle behind smart materials
CO2	Evaluate the working mechanisms of smart fluids
CO3	Appraise the process of self-healing and self-cleaning
CO4	Appraise the potential applications of smart materials

Detailed syllabus

Module No.	Contents	Hours
Module 1	**Introduction to smart materials:** Overview of smart materials. Shape Memory Alloys (SMA), Shape memory effect, Superelasticity or Pseudoelasticity, Phase Transformation phenomenon in SMAs, Types of Shape Memory alloys. Effect of Thermo-Mechanical Treatments, Effects of Aging, Effect of Grain Size, Effect of Deviation from Equiatomic Stoichiometry, Effect of Additive elements, precipitation and applications	**9**
Module 2	**Piezoelectric Materials:** Piezoelectric effect, Direct Piezoelectric effect, Inverse piezoelectric effect, Mechanism and Working of Piezoelectric effect, Applications of piezoelectric devices	**4**
Module 3	**Magnetostrictive Materials and Chromogenic Materials:** Mechanism of magnetostrictive effect, Magnetostrictive effects, Potential applications, Concept of Chromogenic Materials, Classification of Chromogenic Materials, Applications.	**4**
Module 4	**Smart Fluid:** Electro-rheological fluid, Mechanisms of smart fluid, Magneto-Rheological Fluid, Mechanism of strengthening of MR fluid, Mechanism, Applications.	**4**
Module 5	**Self-Healing and self-cleaning materials:** Types of self-healing materials, Self-Healing in Metals, Mechanically Triggered Self-Healing, Ballistic impact self-healing, Thermally Triggered self-Healing, Optically Triggered Healing, Classification of self-cleaning materials, Applications	**7**
	Total Hours	**28**

Books Recommended

1. Mel M. Schwartz, Smart Materials, CRC Press, 2009.
2. Donald J. Leo, Engineering analysis of smart material systems, John Wiley & Sons, 2007.
3. Ajit Behera, *Text Book: Advanced Materials*, Springer , 1st edition, 1550 pages, ISBN: 978-3-030-80359-9, Springer Nature, 2021

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (8th Semester)	**(Honours Elective 6) Porous Materials**	MMT 060	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyse the mechanics and the properties of the porous materials to be used for specific applications
CO2	Assess the various manufacturing methods to decide for their manufacturing, based on the properties required
CO3	Evaluate the mechanical and other properties of the porous materials
CO4	Propose a porous material as well as the route of manufacturing based on the application area

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction:** Porous Materials, Classification of Porous Materials, Methods of Manufacture, their advantages and disadvantages, Structure of porous materials, Properties and Applications,	**10**
Module 2	**Characterisation of Porous Materials:** Porosity, pore size, pore morphology, specific surface area, uniaxial tensile and compressive testing, shear testing, multiaxial testing, fatigue testing, creep testing, indentation and hardness.	**8**
Module 3	**Mechanics of foams:** Deformation mechanisms, tensile behaviour, compressive behaviour, stress-strain curves, effect of strain rate and temperature, anisotropy, energy absorption mechanisms and diagrams,	**8**
Module 4	**Design Analysis:** Property profile, design for fatigue, design for creep, design for packaging and sound absorption, thermal management, cost analysis etc.	**10**
Module 5	**Case studies:** Wood, Cancellous Bone, Cork, Sandwich Panels – structure and mechanical properties	**6**
	Total Hours	**42**

Books Recommended:

1. Porous Materials – Processing and Applications, P.S. Liu, G. F. Chen, Butterworth-Heinemann Publications, 2014
2. Cellular Materials – Structure and Properties, L.J. Gibson, M.F. Ashby, Cambridge University Press, 1997
3. Metal Foams : a Design Guide, Ashby, M. F., Evans, A. G., Fleck, N. A., Gibson, L. J., Hutchinson, J. W., & Wadley, H. N. G., Elseveir., 2000
4. Porous Materials – Process Technology and Applications, Kozo Ishizaki, Sridhar Kumar Naini and Makoto Nanko, Springer-Verlag New York Inc., 1998

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4^{th} Year (8^{th} Semester)	**(Honours Elective 6)** **Advanced Continuous Casting**	MMT 061	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Course Outcomes: At the end of the course, the student will be able to:

CO1	Apply the concept of fluid flow, heat transfer, and numerical methods in the continuous casting process.
CO2	Analyze the different phenomena and solidification process in continuous casting operation.
CO3	Investigate the defects in the continuous casting process and their remedies using recent technology.
CO4	Create a new design in the continuous casting machine using the application of Ansys.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction to continuous casting process:** Different parts of continuous casting, construction and process of continuous casting machine, types of continuous casting, application, advantages and disadvantages of continuous casting. **Basic Phenomena in Continuous Casting Process:** Argon injection, breakout, surface defects, vortex formation, variation interface level and meniscus velocity due to clogging and entrapment of alumina.	**8**
Module 2	**Fluid Flow Mechanism in Continuous Casting:** Steel flow in Continuous casting mold, type of flow, different factors which affects the flow in Continuous Casting mold such as tundish, mold and nozzles geometry, casting speed, nozzle submergence depth, argon gas injection, application of electromagnetic force.	**8**
Module 3	**Solidification and heat transfer mechanism in Continuous Casting:** Initial shell formation, oscillation effect, lubrication mechanism in the mould, heat transfer mechanisms in solidification, shrinkage behavior of casting, mode of heat transfer, interfacial heat transfer coefficient.	**10**
Module 4	**Defects in Continuous Cast materials and remedies:** Defects-oxidation of steel, exogenous inclusion, cracks such as surface cracks, internal cracks, macro-segregation, transversal and longitudinal cracking, causes of these defects and remedies.	**6**
Module 5	**Recent development in continuous casting:** Use of Numerical methods to studies the fluid flow and solidification, reduction technology, MHD technology to control fluid flow in the continuous casting mold, uses of numerical methods for further development of continuous casting design, and application of Ansys in continuous casting etc.	**10**
	Total Hours	**42**

Books Recommended:

1. Principles of Metal Casting, Heine R W, Loper, C.R. Rosenthal, Tata-McGraw Hill Publishing Co Ltd., 1995.
2. Continuous Casting of Steel, W.R. Irving, CRC Press, 1993.
3. Continuous Casting, Michael Vynnycky, Published in Metals, 2019.
4. Continuous Casting: A Revolution in Steel, Tanner, A. Heinrich, Write Stuff Enterprises Inc., 1998.
5. Continuous Casting Vol. III: The Application of Electromagnetic Stirring (EMS) in the Continuous Casting of Steel, Moore. J. J., published by Iron & Steel Society, 1984.
6. On Some Positive Effects of the Swirling flow for continuous Casting: Numerical Study on heat and

mass transfer of steel casting billet moulds, S Kholmatov, VDM Verlag Dr. Muller, 2009

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (8th Semester)	**(Honours Elective 7) Dislocation and Plasticity**	MMT 062	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyze the defects in materials and their role in determining properties of materials
CO2	Interpret the structure of dislocations in various crystals and their characteristics
CO3	Evaluate the interaction of dislocations with precipitates, grain boundaries, solute and other defects and correlate them with various mechanical properties and phenomena in material

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Dislocations in Crystals- Resistance to Dislocation Motion ; Peierls Nebarro Valley, Slip Systems in various crystals, Dislocations and Slips, Critical resolved Shear Stress. Movement of Dislocations- Glide; Kinks, Cross-Slip of dislocations, Climb; Jogs, Superjogs	**8**
Module 2	Dislocation Movement Characteristics, Dislocation Intersection; Step Characteristics, Strain and strain-rate due to dislocation motion; Velocity of Dislocations, Observation of Dislocations; Dislocation Dynamics, Dislocations in various crystal systems, Dislocation Structure in FCC	**10**
Module 3	Dislocations in FCC, Partial Dislocations in FCC, Thompsons Tetrahedron, Dislocation lock in FCC, Other defects in FCC (Twins and Frank Partial) Dislocations in BCC, Dislocation Structure in BCC, Soft core and Hard core for screw dislocations in BCC, Dislocations in HCP, Dislocation Structure in HCP, Burger Vector and Partial Dislocations in HCP	**10**
Module 4	Dislocations in other Crystalline Systems, Dislocation Structure in Ionic Crystal, Dislocation Structure in Superlattices, Stacking fault and Kear-Wilsdorf Lock in Superlattices, Dislocation Interaction in Crystalline Materials, Dislocation Interaction; Strain Hardening, Origin and Nucleation of Dislocations, Multiplication of Dislocations, Solid Solution Strengthening (Interaction of Point defects and Dislocations), Cottrell Atmosphere; Yield Point Phenomenon	**14**
	Total Hours	**42**

Books Recommended:

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

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (8th Semester)	**(Honours Elective 7) Surface Engineering**	MMT 063	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Implement the metallurgical principles behind the surface engineering processes
CO2	Apply different surface modification methods in order to increase the life of the materials.
CO3	Compare the surface engineering methods based on the metallurgical changes occurring during a coating or a surface modification technique
CO4	Monitor and control the engineered surface.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	Introduction to materials, surface, thermodynamics of surface, surface dependent engineering properties, Common surface-initiated engineering failure; mechanism of surface degradation (wear, corrosion and high temperature oxidation). Importance of surface engineering, classification and scope of surface engineering of materials.	**12**
Module 2	Introduction to surface modification and coating techniques. Conventional surface modification methods: flame hardening, induction hardening, carburizing, nitriding, diffusion assisted surface alloying.	**8**
Module 3	Surface Coating by Chemical/electro-chemical Routes, Electro/electroless deposition, anodizing, micro-arc oxidation, Surface Coating by Physical Routes: Physical vapor deposition (Thermal evaporation, sputtering and Ion Plating), Surface Coating by chemical Routes: Chemical vapor deposition. Thermal Spraying (flame spraying, HVOF spraying,), Weld overlaying, laser surface cladding	**14**
Module 4	Advanced surface modification methods: Laser, Plasma and electron beam assisted surface modification. Surface characterization and Testing.	**8**
	Total Hours	**42**

Books Recommended:

1. P. K. Dutta & I. S. Gray, Surface Engineering, Vol. I - III, Royal Society of Chemistry, 1993
2. ASM Hand Book, Vol.5, ASM International, Metals Park, Ohio, 1999
3. Kenneth G. Budinski, Surface Engineering for wear resistance, Prentice Hall, NJ 1988.

Year (Semester)	Course Title	Course Code	L-T-P-Credits
4th Year (8th Semester)	**(Honours Elective 7) Fracture Mechanics**	MMT 064	2-1-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Pre-requisites: None.

Course Outcomes: At the end of the course, the student will be able to:

CO1	Analyse the effects of crack like defects on the performance of automobile/ building structures.
CO2	Critical assessment of crack growth and crack arrest in engineering.
CO3	Ability to apply a variety of crack propagation criteria for determining the critical values of the applied loading and crack length at crack propagation
CO4	Use of learned components to enhance engineering safety.

Detailed Syllabus:

Module No.	Contents	Hours
Module 1	**Fracture mechanics principles:** Linear elastic fracture mechanics (LEFM) and Elastic plastic fracture mechanics (EPFM). Theoretical cohesive strength. Energy based approach to fracture. Griffiths crack theory. Irwin's modifications for elastic-plastic materials. Energy release rate: compliance and strain energy approach. Critical energy release rate and toughness	**12**
Module 2	**Elastic plastic fracture mechanics:** Stress field around a crack: Modes I, II and III. Plane strain and plane stress. Effect of plate thickness. Stress intensity factor. Critical stress intensity factor and fracture toughness.	**9**
Module 3	**Crack-tip stress and displacement fields:** Plastic deformation near the crack tip. Approximate plastic zone size based on von-Mises and Tresca yield criteria. Irwin and Dugdale approaches. Effective crack size. J-Integral: definition and path independence. Equivalence of J, G and K. Crack-tip opening displacement.	**10**
Module 4	**Fracture toughness:** testing. Ductile-brittle transition, impact energy fracture toughness correlation. Diagnostics of Engineering Fractures, Paris Law and Sigmoidal Curve, Crack closure, Techniques in Failure Prevention, Case Studies	**5**
Module 5	**Microstructural aspects of fracture toughness.** Environmental assisted cracking. Mixed mode crack initiation and growth. Fatigue fracture under combined loading,	**6**
	Total Hours	**42**

Books Recommended:

1. Anderson: Fracture Mechanics: Fundamentals and Applications, CRC press, 3rd Ed., 2005
2. Fracture Mechanics – An introduction, E.E. Gdoutus, Springer 2005
3. Elementary Engineering Fracture Mechanics, David Broek, Kluver Academic Publishers Group (Martinus Nijhoff Publishers),1982
4. Deformation and Fracture Mechanics of Engineering Materials, R. W. Hertzberg, Wiley & Sons, 1996
5. Mechanical Metallurgy, Dieter G. E., Mc Graw Hill, 2013.
6. Mechanical Behavior of Materials, T.H. Courtney, McGraw Hills, 1990.

Metallurgical and Materials Engineering Department: Implemented for Batch 2023 and onwards. Total Required Credits: Minimum=160 (I + II Semester =42)

Semester	Course-1	Course-2	Course-3	Course-4	Course-5	Course-6	Course-7	Course-8	Course-9	Course-10	Course-11	Total Credits
III	Electronic, Magnetic and Dielectric Materials	Thermodynamics of Materials	Physical Metallurgy	Mineral Dressing & Principles of Extractive Metallurgy	Probability and Statistics	Entrepreneurship Development	Laboratory Practice in Physical Metallurgy	Laboratory Practice in Mineral Dressing & Principles of Extractive Metallurgy				
	3	3	3	3	3	3	1	1				20
	MMT: 201	MMT: 202	MMT: 203	MMT: 204	MAT: 206	HST: 006	MML: 205	MML: 206				
IV	Phase Transformation and Heat Treatment of Metals	Kinetics of Metallurgical Processes	Non-Ferrous Metal Extraction	Joining of Materials	Numerical Methods	Engineering Economics and Management	Laboratory Practice in Heat Treatment	Laboratory Practice in Joining of Materials				
	3	3	3	3	3	3	1	1				20
	MMT: 250	MMT: 251	MMT: 252	MMT: 253	MAT: 216	HST: 004	MML: 254	MML: 255				
V	Corrosion Engineering	Iron Making	Mechanical Behaviour of Materials	Materials Characterization	**Professional Elective – I** Advanced Manufacturing Processes / Physical Metallurgy of Light Metals and Alloys	**Institute Open Elective – I** *(For Non-MMED)* Electrical and Electronic Engineering Materials / Introduction to Materials Science & Engineering	Laboratory Practice in Corrosion Engineering	Laboratory Practice in Mechanical Behaviour of Materials	Laboratory Practice in Materials Characterization			
	3	3	3	3	3	3	1	1	1			21
	MMT: 301	MMT: 302	MMT: 303	MMT: 304	MMT: 001 / MMT: 002	MMT: 016 / MMT:017	MML: 308	MML: 309	MML: 310			
VI	Ceramic Technology	Steel Making	Powder Metallurgy	Mechanical Working of Materials	**Professional Elective-II** Thermal Analysis & Spectroscopy / Fuels, Furnaces & Refractories	**Institute Open Elective –II** (For Non-MMED) Nanomaterials / Energy Materials	Laboratory Practice in Ceramic Technology	Laboratory Practice in Mechanical Working of Materials	Industrial Training / Internship	Seminar		
	3	3	3	3	3	3	1	1	1	1		22
	MMT: 351	MMT: 352	MMT: 353	MMT: 354	MMT: 050 / MMT: 051	MMT : 065 / MMT: 066	MML: 358	MML: 359	MMI: 360	MMS: 361		
VII	Metal Casting	Polymer Technology	**Professional Elective - III** Composite Materials) / High Temperature Materials	**Professional Elective - IV** Selection and properties of materials / Tribology of Engineering Materials	**Professional Elective - V** Science and Technology of Thin Films / Thermo-mechanical processing	Laboratory Practice in Metal Casting	Laboratory Practice in Polymer Technology	Project Preliminary Work				
	3	3	3	3	3	1	1	2				19
	MMT: 401	MMT: 402	MMT: 005 / MMT: 006	MMT: 007 / MMT: 008	MMT: 009 / MMT: 010	MML: 409	MML: 410	MMP: 411				
VIII	Non-Destructive Testing and Evaluation	**Professional Elective – VI** Failure Analysis / Alternate Methods of Iron Making	**Professional Elective - VII** Introduction to Multicomponent and High-Entropy Alloys / Bio-Materials	Laboratory Practice in Non-Destructive Testing	Major Project							
	3	3	3	1	6							16
	MMT: 451	MMT: 054 / MMT 055	MMT: 056 / MMT: 057	MML:456	MMP:457							
												160

Metallurgical and Materials Engineering Department: Implemented for Batch 2023 and onwards. Total Required Credits: Honours = 180 (I + II Semester =42)

Semester	Course-1	Course-2	Course-3	Course-4	Course-5	Course-6	Course-7	Course-8	Course-9	Course-10	Course-11	Total Credits
III	Electronic, Magnetic and Di-electric Materials	Thermodynamics of Materials	Physical Metallurgy	Mineral Dressing & Principles of Extractive Metallurgy	Probability and Statistics	Entrepreneurship Development	Laboratory Practice in Physical Metallurgy	Laboratory Practice in Mineral Dressing & Principles of Extractive Metallurgy				
	3	3	3	3	3	3	1	1				20
	MMT: 201	MMT: 202	MMT: 203	MMT: 204	MAT: 206	HST: 006	MML: 205	MML: 206				
IV	Phase Transformation and Heat Treatment of Metals	Kinetics of Metallurgical Processes	Non-Ferrous Metal Extraction	Joining of Materials	Numerical Methods	Engineering Economics and Management	Laboratory Practice in Heat Treatment	Laboratory Practice in Joining of Materials				
	3	3	3	3	3	3	1	1				20
	MMT: 250	MMT: 251	MMT: 252	MMT: 253	MAT: 216	HST: 004	MML: 254	MML: 255				
V	Corrosion Engineering	Iron Making	Mechanical Behaviour of Materials	Materials Characterization	**Professional Elective – I** Advanced Manufacturing Processes / Physical Metallurgy of Light Metals and Alloys	**Institute Open Elective – I** (For Non-MMED) Electrical and Electronic Engineering Materials / Introduction to Materials Science & Engineering	Laboratory Practice in Corrosion Engineering	Laboratory Practice in Mechanical Behaviour of Materials	Laboratory Practice in Materials Characterization	**Honours Elective-I** Introduction to Energy Materials / Transport Phenomena in Materials Engineering		
	3	3	3	3	3	3	1	1	1	3		24
	MMT: 301	MMT: 302	MMT: 303	MMT: 304	MMT: 001 / MMT: 002	MMT: 016 / MMT:017	MML: 308	MML: 309	MML: 310	MMT: 003 / MMT: 004		
VI	Ceramic Technology	Steel Making	Powder Metallurgy	Mechanical Working of Materials	**Professional Elective – II** Thermal Analysis & Spectroscopy / Fuels, Furnaces & Refractories	**Institute Open Elective – II** (For Non-MMED) Nanomaterials / Energy Materials	Laboratory Practice in Ceramic Technology	Laboratory Practice in Mechanical Working of Materials	Industrial Training / Internship	Seminar	**Honours Elective - II** Protective Coatings / Electron Microscopy	
	3	3	3	3	3	3	1	1	1	1	3	25
	MMT: 351	MMT: 352	MMT: 353	MMT: 354	MMT: 050 / MMT: 051	MMT : 065 / MMT: 066	MML: 358	MML: 359	MMI: 360	MMS: 361	MMT: 052 / MMT: 053	
VII	Metal Casting	Polymer Technology	**Professional Elective - III** Composite Materials) / High Temperature Materials	**Professional Elective - IV** Selection and properties of materials / Tribology of Engineering Materials	**Professional Elective - V** Science and Technology of Thin Films / Thermo-mechanical processing	Laboratory Practice in Metal Casting	Laboratory Practice in Polymer Technology	Project Preliminary Work	**Honours Elective-III** Additive Manufacturing / Creep, Fatigue & Fracture	**Honours Elective-IV** Nano Materials / Fundamentals of Electro-Chemistry / Severe plastic deformation		
	3	3	3	3	3	1	1	2	3	3		25
	MMT: 401	MMT: 402	MMT: 005 / MMT: 006	MMT: 007 / MMT: 008	MMT: 009 / MMT: 010	MML: 409	MML: 410	MMP: 411	MMT: 011 / MMT: 012	MMT: 013/ MMT: 014 / MMT: 015		
VIII	Non-Destructive Testing and Evaluation	**Professional Elective – VI** Failure Analysis / Alternate Methods of Iron Making	**Professional Elective - VII** Introduction to Multicomponent and High-Entropy Alloys / Bio-Materials	Laboratory Practice in Non-Destructive Testing	Major Project	**Honours Elective - V** Secondary Steel Making / Smart Materials	**Honours Elective - VI** Porous Materials / Advanced Continuous Casting	**Honours Elective - VII** Dislocation & Plasticity / Surface Engineering / Fracture Mechanics				
	3	3	3	1	6	2	3	3				24
	MMT: 451	MMT: 054 / MMT 055	MMT: 056 / MMT: 057	MML:456	MMP:457	MMT: 058 / MMT: 059	MMT: 060 / MMT: 061	MMT: 062 / MMT: 063/ MMT: 064				
												180