CURRICULUM & SYLLABI
B.Tech. METALLURGICAL AND MATERIALS ENGINEERING

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

Table of Contents

VISION AND MISSION OF THE INSTITUTE 3
VISION AND MISSION OF THE DEPARTMENT 3
PROGRAM EDUCATIONAL OBJECTIVES 4
PROGRAM OUTCOMES 5
PROGRAM SPECIFIC OUTCOMES 5
CURRICULUM 6
THE OVERALL CREDIT STRUCTURE 13
SYLLABI 15
MINOR: MATERIALS ENGINEERING 161
HONORS: METALLURGICAL AND MATERIALS ENGINEERING 172

Vision and Mission of the Institute
National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department
METALLURGICAL AND MATERIALS Engineering

VISION

Attain global recognition in research and training to meet challenging needs of Metallurgical and Materials Engineering with ethical and moral responsibility towards society.

MISSION

- Provide outstanding technical education for analysis, design and operation of metallurgical and materials systems.
- Keep abreast with rapid strides of technology and improve academic standards through innovative teaching and learning processes.
- Engage in quality research in metallurgical, materials and allied engineering areas.
- Develop linkages with leading academic, research, and industrial organizations for societal benefit.

Program: B.Tech. Metallurgical and Materials Engineering

Program Educational Objectives

PEO-1	Apply knowledge of basic sciences, metallurgical and materials engineering for the development of materials through extraction, refining, processing and manufacturing.
PEO-2	Model, design, process, characterize and evaluate materials for generic, industrial and strategic applications.
PEO-3	Work effectively as an individual and in a team in inter- and multi-disciplinary projects with ethics and professionalism
PEO-4	Pursue life-long learning to enhance knowledge and professional skills for career growth with social and environmental responsibility

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4
Provide outstanding technical education for analysis, design and operation of metallurgical and materials systems.	3	3	-	-
Keep abreast with rapid strides of technology and improve academic standards through innovative teaching and learning processes.	3	3	-	3
Engage in quality research in metallurgical, materials and allied engineering areas.	3	3	3	-
Develop linkages with leading academic, research, and industrial organizations for societal benefit.	-	-	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: B.Tech. Metallurgical and Materials Engineering

Program Outcomes

PO-1	**Engineering knowledge**: Apply the knowledge of mathematics, science, Engineering fundamentals, and Metallurgical and Materials Engineering engineering to the solution of complex engineering problems.
PO-2	**Problem analysis:** Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences
PO-3	**Design/Development of solutions:** Design solutions for complex Metallurgical and Materials engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO-4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO-5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex Metallurgical and Materials Engineering engineering activities with an understanding of the limitations.
PO-6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO-7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO-8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO-9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO-10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO-11	**Project management and Finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO-12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO-1	Select/design processes for extraction and manufacturing of ferrous and non-ferrous metals and alloys
PSO-2	Apply thermodynamic, physical and mechanical metallurgy principles to improve the performance and service life of the components
PSO-3	Process and develop ceramic, polymer, composites and functional materials for specific applications
PSO-4	Evaluate and assess structure and properties of materials using characterization techniques

CURRICULUM
B.Tech. Metallurgical and Materials Engineering

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA1161	Linear Algebra, Calculus and Ordinary Differential Equations	3-0-0	3
2	CY1161	Engineering Chemistry	3-0-2	4
3	MM1101	Design Thinking	0-1-4	3
4	MM1103	Introduction to Materials Science and Engineering	3-0-0	3
5	ME1161	Engineering Drawing	1-0-4	3
6	ME1165	Engineering Workshop Practice	0-1-2	2
7	IC1101	EAA-I (Games & Sports / Yoga & Wellness)	0-0-0	0
		Total Credits		**18**

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA1162	Integral and Vector Calculus, Laplace Transforms	3-0-0	3
2	PH1161	Engineering Physics	3-0-2	4
3	HS1161	English for Technical Communication	2-0-2	3
4	CS1101	Programming and Data Structures	3-0-0	3
5	CS1103	Programming and Data Structures laboratory	0-1-2	2
6	EE1161	Basic Electrical & Electronics Engg.	3-0-0	3
7	BT1161	Biology for Engineers	2-0-0	2
8	IC1102	EAA-II (Games & Sports / Yoga & Wellness)	0-0-0	0
		Total Credits		**20**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM1201	Physical Metallurgy	2-1-0	3
2	MM1203	Metallurgical Thermodynamics	3-1-0	4
3	MM1205	Unit Processes in Extractive Metallurgy	3-0-0	3
4	MM1207	Transport Phenomena	3-1-0	4
5	MM1209	Electronic and Magnetic Materials	3-0-0	3
6	MM1211	Physical Metallurgy and Metallography Laboratory	0-1-2	2
7	MM1213	Unit Processes in Extractive Metallurgy Laboratory	0-1-2	2
			Total Credits	**21**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA1263	Partial Differential Equations, Statistics and Numerical Methods	3-0-0	3
2	MM1202	Phase Transformations and Heat Treatment	3-1-0	4
3	MM1204	Ferrous Extractive Metallurgy	3-1-0	4
4	MM1206	Casting and Solidification Processing	3-0-0	3
5	MM1208	Ceramics and Composites Technology	3-0-0	3
6	MM1210	Phase Transformations and Heat Treatment Laboratory	0-1-2	2
7	MM1212	Solidification Processing Laboratory	0-1-2	2
			Total Credits	**21**

5th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MS1262	Business Essentials for Engineers	3-0-0	3
2	MM1301	Corrosion Engineering	3-0-2	4
3	MM1303	Powder Metallurgy	3-0-0	3
4	MM1305	Mechanical Metallurgy	2-1-0	3
5	MM13XX	Professional Elective – I	3-0-0	3
6	MM1381	Fractal Course - I	1-0-0	0.5
7	MM1307	Powder Metallurgy Laboratory	0-1-2	2
8	MM1309	Mechanical Metallurgy Laboratory	0-1-2	2
		Total Credits		**20.5**

6th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM1302	Computational Materials Engineering	3-0-0	3
2	MM1304	Non-Ferrous Extractive Metallurgy	3-1-0	4
3	MM13XX	Professional Elective – II	3-0-0	3
4	MM13XX	Professional Elective - III	3-0-0	3
5	MM1306	Product Development	0-1-4	3
6	MM1382	Fractal Course - II	1-0-0	0.5
7	MM1308	Computational Materials Engineering Laboratory	0-1-2	2
8	MM1310	Materials Characterization Laboratory	0-1-2	2
		Total Credits		**20.5**

7th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM1401	Metal Joining	3-0-0	3
2	MM14XX	Professional Elective - IV	3-0-0	3
3	MM14XX	Professional Elective - V	3-0-0	3
4	MM14XX	Open Elective – I	2-0-0	2
5	MM1403	Metal Joining Laboratory	0-0-2	1
6	MM1405	Materials Processing Laboratory	0-0-2	1
7	MM1489	Seminar & Technical Writing	0-0-0	2
8	MM1491	Short Term Industrial / Research Experience*	0-0-0	2
9	MM1495	Minor Project	0-0-0	2
		Total Credits		**19**

8th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM14XX	Professional Elective - VI	3-0-0	3
2	MM14XX	Professional Elective - VII	3-0-0	3
3	MM14XX	Professional Elective – VIII/Open Elective II / Innovation and Entrepreneurship	3-0-0	3
4	MM1498	Major Project	0-0-0	6
		Total Credits		**15**

Professional Elective Courses:

Professional Elective-I		
S.No.	**Code**	**Course Title**
1	MM1321	Fuels and Refractories
2	MM1323	Advanced Metallurgical Thermodynamics
3	MM1325	Ferroalloy Technology
4	MM1327	Nuclear Materials
5	MM1329	Mineral Processing

Professional Elective-II, III		
S.No.	**Code**	**Course Title**
1	MM1322	Machine Learning for Materials Engineering
2	MM1324	Functional Materials
3	MM1326	Energy Materials
4	MM1328	Introduction to Nano Science and Technology
5	MM1331	Special Steels
6	MM1332	Creep, Fatigue and Fracture
7	MM1334	Materials Characterization
8	CH1328	Polymer Technology
9	ME1330	Finite Element Method

Professional Elective-IV, V		
S.No.	**Code**	**Course Title**
1	MM1421	Physical Metallurgy of Non-Ferrous Metals and Alloys
2	MM1423	Materials Selection and Design
3	MM1425	Surface Engineering
4	MM1433	Metal forming
5	MM1435	Metallurgical Failure Analysis
6	MM1437	Non-Destructive Testing
7	MM1439	Pollution and its Control in Metallurgical Industries
8	CH1328	Polymer Technology

Professional Elective-VI, VII, and VIII		
S.No.	**Code**	**Course Title**
1	MM1422	Materials for Bio-Applications
2	MM1424	Materials for High Temperature Applications
3	MM1426	Advanced Engineering Materials
4	MM1428	Refractory and Rare Metal Extraction
5	MM1430	Recycling of materials
6	MM1432	Materials for Extreme Environments
7	MM1434	Smart Materials
8	MM1436	3D Printing Technology

Basic Science Courses

S.No.	Code	Course Title	L-T-P	Credits
1	MA1161	Linear Algebra, Calculus and Ordinary Differential Equations	3-0-0	3
2	CY1161	Engineering Chemistry	3-0-2	4
3	MA1162	Integral and Vector Calculus, Laplace Transforms	3-0-0	3
4	PH1161	Engineering Physics	3-0-2	4
5	MA1263	Partial Differential Equations, Statistics and Numerical Methods	3-0-0	3

Engineering Science Courses

S.No.	Code	Course Title	L-T-P	Credits
1	EE1161	Basic Electrical & Electronics Engg.	3-0-0	3
2	ME1161	Engineering Drawing	1-0-4	3
3	ME 1165	Engineering Workshop Practice	0-1-2	2
4	CS1101	Programming and Data Structures	3-0-0	3
5	CS1103	Programming and Data Structures laboratory	0-1-2	2
6	BT1161	Biology for Engineers	2-0-0	2

Humanities and Social Science Courses

S.No.	Code	Course Title	L-T-P	Credits
1	HS1161	English for Technical Communication	2-0-2	3
2	IC1101	Extra Academic Activity - I	0-0-0	0
3	IC1102	Extra Academic Activity - II	0-0-0	0
4	MS1262	Business Essentials for Engineers	3-0-0	3

The Overall Credit Structure

Course Category	Credits
Basic Science	17
Engineering Science	15
Humanities and Social Sciences	6
Program Core	88
Professional Elective	24
Open Elective	5
Total Graded Credit Requirement	155

Minor in Materials Engineering:

Code	Course Title	L-T-P	Credits
MM1M01	Structure and Properties of Materials	3-0-0	3
MM1M02	Engineering Materials	3-0-0	3
MM1M03	Characterization Techniques	3-0-0	3
MM1M04	Materials Degradation	3-0-0	3
MM1M05	Materials Testing	3-0-0	3
		Total	**15**

Honors in Metallurgical and Materials Engineering:

Code	Course Title	L-T-P	Credits
MM1H01	Diffusion in Solids	3-0-0	3
MM26003	Ferrous Welding Metallurgy	3-0-0	3
MM16022	Additive Manufacturing	3-0-0	3
MM16042	Aerospace Materials	3-0-0	3
MM1H05	Advanced ceramics for strategic applications (Online course-NPTEL)	3-0-0	3
		Total	**15**

SYLLABI

B.Tech. Metallurgical and Materials Engineering

1st Semester

MA1161 **3-0-0 (3)**

Linear Algebra, Calculus and Ordinary Differential Equations

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand solve the consistent system of linear equations
CO-2	Apply orthogonal transformations to a quadratic form
CO-3	Determine the series expansion of a given function
CO-4	Explore the properties of functions of several variables
CO-5	Solve arbitrary order linear differential equations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	1	2	1	–	–	–	–	–	–	–	1	1	1	1
CO-2	3	3	1	2	1	–	–	–	–	–	–	–	–	–	1	–
CO-3	3	3	1	2	1	–	–	–	–	–	–	–	1	–	1	1
CO-4	3	3	1	2	1	–	–	–	–	–	–	–	–	–	–	1
CO-5	3	3	1	2	1	–	–	–	–	–	–	–	2	1	1	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Linear Algebra: Vectors in the vector space $\mathbb{R}^n$; Notion of linear independence and dependence, linear span of a set of vectors, basis of a vector space; Systems of linear equations, matrices and Gauss elimination, row space, null space, and column space, rank of a matrix; Linear transformations from $\mathbb{R}^n$ to $\mathbb{R}^m$, matrix of a linear transformation, change of basis and similarity, rank-nullity theorem; Inner products, Gram-Schmidt process, Eigenvalues and eigenvectors, eigenvalues of special matrices (symmetric, Hermitian, skew-symmetric, skew-Hermitian, orthogonal, unitary), diagonalization by similarity and orthogonal transformations.

Differential Calculus: Taylor's theorem with remainders; Taylor's and Maclaurin's expansions; Asymptotes; Curve tracing (only polar curves); Functions of several variables – continuity, differentiability, partial differentiation, Euler's theorem, change of variables, Jacobians, Functional dependence; Maxima and minima of functions of several variables (2 and 3 variables) - Lagrange's method of multipliers.

Ordinary Differential Equations: First order differential equations - Basic definitions, Geometric interpretation of solutions of first order ODE $y' = f(x, y)$, Exact differential equations, Integrating factors, Linear equation, Reducible to linear form: Bernoulli's equations; Orthogonal trajectories; Higher order linear differential equations with constant coefficients - Cauchy-Euler and Legendre's differential equations, Method of variation of parameters - System of linear differential equations; Applications to physical problems.

Learning Resources:

Text Books:

1. Howard Anton and Chris Rorres, Elementary Linear Algebra with Supplementary Applications, John Wiley & Sons, 2014, Eleventh Edition.
2. George B. Thomas and Ross L. Finney, Calculus and Analytic Geometry, Pearson, 2020, Ninth Edition.
3. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2015, Eighth Edition.

Reference Books:

1. Dennis G. Zill, Jones & Bartlett Learning, Advanced Engineering Mathematics, 2018, Sixth Edition
2. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2016, Fifth Edition.

CY1161 **3-0-2 (4)**

Engineering Chemistry

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand the basic concepts of chemistry relevant to materials.
CO2	Apply electrochemical concepts for energy harvesting, conversion and storage.
CO3	Analyze the properties of materials for various applications.
CO4	Comprehend the concepts of instrumentation principles, Spectroscopy and procedures involved in characterization of materials
CO5	To analyze the metal contents from the ores by understanding the redox process
CO6	To determine the rate of corrosion by a redox reaction and understand the concept of adsorption

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	2	2	1	-
CO-3	3	2	-	-	-	-	-	-	-	-	-	-	2	2	1	-
CO-4	3	-	-	-	-	-	-	-	-	-	-	-	2	2	1	-
CO-5	3	3	3	-	2	-	2	-	-	-	-	-	1	1	-	-
CO-6	3	3	3	-	2	2	-	-	-	1	-	-	1	-	2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Chemical Kinetics and Thermodynamics: Order of a Reaction, Theories of Reaction Rates. Homogeneous and Heterogeneous Catalysis. Thermodynamic variables, Laws of Thermodynamics, Thermodynamic Relationships and Applications.

Electrochemistry and Energy Systems: Introduction to Electrochemistry, Nernst's law and its applications. Batteries, fuel cell and photo-electrochemical systems. Corrosion and its prevention.

Transition Metal Chemistry and Organometallic Chemistry: Bonding in transition metal complexes; Crystal field and MO Theories, Jahn-Teller effect. Properties of Coordination complexes; Metal Carbonyls, EAN and 18-electron rule, Ligands and hapticity; Type of reactions: Oxidative addition, Reductive elimination, Migratory insertion, Hydrogenation, Hydro formylation, Monsanto process and Wacker process.

Engineering Materials: Inorganic and Organic Semiconductors, Magnetic materials, Liquid crystals, Superconductors, Photo conducting Materials and conducting polymers. **Chromatographic and Spectroscopic Methods:** Liquid Chromatographic and Gas Chromatographic methods. UV-VIS, spectroscopy, Infrared spectroscopy, NMR spectroscopy.

List of Experiments:

1. Standardization $KMnO_4$ solution

2. Estimation of metal content in an ore
3. Estimation of Calcium in milk powder by complexometry
4. Extraction and identification of DNA from green peas/onions
5. Estimation of iodine in iodized common salt
6. Blue printing of an object by photochemical reaction
7. Kinetics of acid hydrolysis of methyl acetate
8. Determination of acid strength in citrus fruit
9. Verification of Beer-Lambert Law and estimation of concentration of food color
10. Evaluation of E^o values of $Zn|Zn^{2+}$ and $Cu|Cu^{2+}$ Electrodes and measure the emf by constructing the Daniel cell
11. Estimation of phosphoric acid in soft drinks by pH metry
12. Separation of natural pigments from mixture using paper chromatography
13. Determination of efficiency of a corrosion inhibitor
14. Verification of Freundlich adsorption isotherm
15. Preparation of a polymer and its analysis
16. Estimation of active pharmaceutical ingredient in a drug

Learning Resources:

Text Books:

1. Shashi Chawla, A Text Book of Engineering Chemistry, Danpathrao & Co. Publications, 2007, 6th India reprint edition.
2. Ashutosh Kar, Text Book of Engineering Chemistry, ED-Tech Publications, 2018.
3. William Kemp, Organic Spectroscopy, Macmillan Education, Limited, 2017.
4. Introductory Chemistry laboratory manual: Concepts and Critical Thinking, Charles Corwin, Pearson Education, 2012.
5. Investigating Chemistry: Laboratory Manual, David Collins, Freeman & Co., 2006.

Reference Books:

1. Michael F. Ashb, David R.H. Jones, Engineering Materials, Elsevier Science, 2012
2. V. Raghava, Material Science and Engineering, PHI Learning, 2015
3. J.M. Martin, Materials for Engineering, Elsevier Science, 20006
4. Peter Atkins, Julio de Paula, James Keeler, Physical Chemistry, Oxford University Press, 2018.

MM1101 **0-1-4 (3)**

Design Thinking

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify user needs.
CO-2	Define problems to stimulate ideation.
CO-3	Ideate on problems to propose solutions by working collaboratively.
CO-4	Test aspects of proposed solutions.
CO-5	Improve solutions by gaining user feedback.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	2	2	3	3	3	2	2	3	3	2	3	2	1	3	2
CO-2	2	2	2	3	3	3	2	2	3	3	2	3	2	1	3	2
CO-3	2	2	2	3	3	3	2	2	3	3	2	3	2	1	3	2
CO-4	2	2	2	3	3	3	2	2	3	3	2	3	2	1	3	2
CO-5	2	2	2	3	3	3	2	2	3	3	2	3	2	1	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Engineering: "Engineering" as a vehicle for social and economic development; the impact of science/engineering on our day-to-day lives; the process of engineering a product; various career options.

Introduction and identifying the need: Understanding the unique needs of the user - empathize - define - ideate - prototype - test. Case Studies - Develop an appreciation for the design process and its application in specific settings (Guest lectures, Videos, Field visits, Interplay lectures of design-based movies).

Problem Formulation: Framing a problem statement neutrally using adequate checks. Case studies.

Concept Generation: Generate multiple concepts using various creativity tools and thinking styles.

Prototyping: Select from ideas and make quick prototypes (mock-ups) using available material.

Evaluation: Iterative process of ideation, prototyping and testing-Take the mock-ups to users for feedback and iterate the process until users feel delighted.

Activities: Some activities planned as a part of this course, includes:

- Field Visits
- Case Studies on innovation, failures etc.
- Guest lectures on role of materials in designing components
- Group Discussions
- Presentation by student
- Experiential learning workshops

Learning Resources:

1. Andrew Pressman, Design Thinking: A guide to creative problem solving for everyone, Routledge Taylor and Francis group, 2019.
2. Tim Brown, Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation, Harper Business, 2019.
3. George E. Dieter, Linda C. Schmidt, Engineering Design 6 Ed., Tata McGraw Hill, 2022
4. Ulrich, K., Eppinger, S. and Yang, M, Product Design and Development 7 Ed., McGraw Hill, 2020

MM1103 **3-0-0 (3)**

Introduction to Materials Science and Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	List various advanced materials and their need for building modern industry.
CO-2	Illustrate crystal systems and relevant calculations.
CO-3	Categorize imperfections in solids.
CO-4	Examine the types of solid solutions and their formation.
CO-5	Summarize properties of engineering materials.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	–	2	2	–
CO-2	3	–	–	–	–	–	–	–	–	–	–	–	–	2	2	–
CO-3	3	–	–	–	–	–	–	–	–	–	–	–	–	2	2	–
CO-4	3	–	–	–	–	–	–	–	–	–	–	–	–	2	2	–
CO-5	3	–	–	–	–	–	–	–	–	–	–	–	–	2	2	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Historical Perspective, Importance of Materials Science and Engineering, Classification of Materials, Advanced Materials, Modern Materials' Needs.

The Structure of Crystalline Solids: Unit Cells, Metallic Crystal Structures, Density Computations, Polymorphism and Allotropy, Crystal Systems, Crystallographic Directions and Planes, Linear and Planar Densities, Single Crystals, Polycrystalline Materials, Anisotropy, Nanocrystalline Solids

Structure of Ceramics and Glasses, Structure of Polymers, Structure of Composite, Structure of Electronic Materials.

Imperfections in Solids: Point defects - Vacancies and Self-Interstitials, Linear Defects – Dislocations; Interfacial (planar) Defects, Bulk or Volume Defects, Effect of imperfections on properties.

Solid Solutions: Types of solid solutions – substitutional solid solutions, interstitial solid solutions, Hume Rothery's rules, intermediate phases.

Properties of materials: Physical properties, Thermal Properties, Electrical Properties, Magnetic Properties, Optical Properties, Mechanical properties, Structure-property correlations in materials.

Learning Resources:

Text Books:

1. William D. Callister, Jr., Materials Science and Engineering-An Introduction, John Wiley & Sons, Inc., 2007, 7th Edition.

2. V. Raghavan, Materials Science and Engineering – A First Course, Prentice Hall of India Private Limited, 2015, 6th Edition.

Reference Books:

1. Donald R. Askeland, Pradeep P. Phule, The Science and Engineering of Materials, Thomson Learning, 2007, 5th Edition.
2. G. S. Upadhyaya and Anish Upadhyaya, Materials Science and Engineering, Viva Books Private Limited, 2006.

ME1161 **1-0-4 (3)**

Engineering Drawing

Pre-Requisites: **None**

Course Outcomes:

CO1	Apply BIS standards and conventions while drawing Lines, printing Letters and showing Dimensions
CO2	Classify the systems of projection with respect to the observer, object and the reference planes.
CO3	Construct orthographic views of an object when its position with respect to the reference planes is defined.
CO4	Analyse the internal details of an object through sectional views
CO5	Develop 3D Isometric View from 2D orthographic views

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-	-
CO2	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-	-
CO3	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-	-
CO4	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-	-
CO5	1	1	1	-	-	-	1	1	3	3	-	-	-	-	-	-

Syllabus:

Introduction: Drawing instruments and their uses, Types of lines, Lettering, General rules for dimensioning, Geometrical constructions using instruments. (Conventional)

Orthographic Projection: Methods of projection, Principles of Orthographic projection, First angle versus third angle of projection, Six views of an object, Conventions. (Conventional)

Projection of Points: Projections of points when they are situated in different quadrants. (Conventional)

Projections of Lines: Projections of a line parallel to one of the reference planes and inclined to the other, line inclined to both the reference planes, Traces. (Conventional)

Fundamentals of AutoCAD: Introduction to Auto-CAD, DRAW tools, modify tools, text, dimension, properties. (AutoCAD)

Projections of Planes: Projections of a plane perpendicular to one of the reference planes and inclined to the other, Oblique planes. (AutoCAD)

Projections of Solids: Projections of solids whose axis is parallel to one of the reference planes and inclined to the other, axis inclined to both the planes. (AutoCAD)

Section of Solids: Sectional planes, Sectional views - Prism, pyramid, cylinder and cone, true shape of the section. (AutoCAD)

Isometric Views: Isometric axes, Isometric lines, Isometric Planes, Isometric scale, Isometric Views,

Isometric projections. (AutoCAD)

Learning Resources:

Text Books:

1. N.D. Bhatt, V.M. Panchal, Engineering Graphics, Charotar Publishers, 2016, 53rd Edition.

Reference Books:

1. B. Agarwal, Engineering Drawing, 2015, McGraw Hill Education, 2015, 2nd Edition.
2. S. Tickoo, Auto CAD 2017 for Engineers & Designers, Dreamtech, 2016, 23rd Edition

ME1165 **0-1-2 (2)**

Engineering Workshop Practice

Pre-requisites: **None**

Course Outcomes:

CO-1	Identify workshop tools and their operational capabilities Credits
CO-2	Practice on manufacturing of components using workshop trades including fitting, foundry and welding
CO-3	Apply suitable tools for machining processes including turning, facing, thread cutting and tapping
CO-4	Apply basic electrical engineering knowledge for House Wiring Practice

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	1	-		1	-	-	2	2	-	-	2	-
CO-2	3	3	1	-	2	1	-	-	2	2	-	-	2	-
CO-3	3	3	1	-	2	1	-	-	2	2	-	-	2	-
CO-4	3	3	1	-	2	1	-	-	2	2	-	-	2	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Demonstration: Safety practices and precautions to be observed in workshop.

Fitting Trade: Demonstration and practice of fitting tools, Preparation of T-Shape, Dovetail Joint. Carpentry: Demonstration and practice of carpentry tools, Preparation of Cross Half lap joint and Mortise Tenon Joint.

Machine shop: Demonstration and practice on Lathe Machine, Preparation of work pieces involving Facing, Plane Turning, step turning, knurling and parting operations.

House Wiring: Demonstration and practice on Electrical tools, wiring and earthing, Exercises on Staircase Wiring & Godown wiring.

Power Tools: Demonstration and practice on Power tools (Bosch Power Tools) and Safety Practices.

Foundry Trade: Demonstration and practice on Moulding tools and processes, Preparation of Green Sand Moulds for given Patterns.

Welding Shop: Demonstration and practice on Arc Welding and Gas welding. Preparation of Lap joint and Butt joint.

Learning Resources

Text Books:

1. Felix W., Basic Workshop Technology: Manufacturing Process, Independently Published, 2019.
2. Bruce J. Black, Workshop Processes, Practices and Materials, Routledge publishers, 2015, 5th Edition.
3. B.S. Raghuwanshi, A Course in Workshop Technology Vol I. & II, Dhanpat Rai & Co., 2015 & 2017.

Reference Books:

1. S. K. Hajra Choudhury, and Nirjahar Roy, Elements of Workshop Technology, Vol. I, Media Promoters and Publishers, Mumbai. 2007, 14th Edition.
2. S. K. Hajra Choudhury and Nirjahar Roy, Elements of Workshop Technology, Vol. II, Media Promoters and Publishers, Mumbai. 2007, 12th edition
3. H. S. Bawa, Workshop Practice Tata-McGraw Hill, 2009, 2nd Edition
4. Arthur R. Gill, Peter Smid, Steve F. Krar, Technology of Machine Tools, McGraw Hill Education,2010, 7th Edition.
5. Ramesh Babu.V., Engineering Practices Laboratory Manual, VRB Publishers, Chennai, 2019-20, Revised Edition
6. T.Jeyapoovan, Engineering Practices Lab Manual; Vikas Publishers, 2008, 4th Edition
7. John K.C.,Mechanical Workshop Practice; PHI, 2010, 2nd Edition
8. Soni P.M. & Upadhyay P.A.; Atul Prakashan, Wiring Estimating, Costing and Contracting; 2021-22

Online Resources:

1. Different Trade E-Books (Fitting, Plumbing, Welding, Carpentry, Foundryman, Turner and House Wiring etc.) developed by National Instructional Media Institute, Chennai. Directorate General of Training, Ministry of Skill Development & Entrepreneurship, Govt. of India. (https://bharatskills.gov.in).

.

2nd Semester

MA1162 **3-0-0 (3)**

Integral and Vector Calculus, Laplace and Fourier Transforms

Pre-Requisites: **MA1161**

Course Outcomes:

CO-1	Analyze improper integrals for extracting certain properties of beta and gamma integrals.
CO-2	Evaluate multiple integrals in various coordinate systems.
CO-3	Apply the concepts of gradient, divergence and curl of scalar and vector point functions to formulate engineering problems.
CO-4	Convert line integrals into area integrals and surface integrals into volume integrals.
CO-5	Apply Laplace transforms to solve physical problems arising in engineering.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-2	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-3	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-4	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-5	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-6	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Integral Calculus: The concept of the convergence of improper integrals; The convergence of Beta and Gamma integrals, and their simple properties; Evaluation of integrals using Leibniz formula; Evaluation of double and triple integrals; Change of variables in double and triple integrals.

Vector Calculus: Scalar and vector fields; Vector differentiation; Level surfaces; Directional derivative; Gradient of a scalar field; Divergence and curl of a vector field; Laplacian operator; Parametrization of curves and surfaces; Line, surface and volume integrals; Green's theorem in a plane; Stoke's theorem; Gauss divergence theorem.

Laplace Transforms: Laplace transforms; Inverse Laplace transforms; Properties of Laplace transforms; Laplace transforms of unit step, impulse and periodic functions; Convolution theorem; Applications of Laplace transforms - solving certain initial value problems - solving system of linear differential equations - finding responses of systems to various inputs viz. sinusoidal inputs acting over a time interval, rectangular waves, impulses

Fourier Transforms: Fourier transformation and inverse transforms - sine, cosine transformations and inverse transforms

Learning Resources:

Text Books:

1. George B. Thomas and Ross L. Finney, Calculus and Analytic Geometry, Pearson, 2020, Ninth Edition

2. Dennis G. Zill, Advanced Engineering Mathematics, Jones & Bartlett Learning, 2018, Sixth Edition

Reference Books:

1. Maurice D. Weir, Joel Hass and Christopher Heil, Thomas' Calculus: Early Transcendentals, Pearson, 2014, Thirteenth Edition
2. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2015, Eighth Edition
3. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2016, Fifth Edition

PH1161 **3-0-2 (4)**

Engineering Physics
(with integrated lab)

Pre-Requisites: **None**

Course Outcomes:

At the end of the course, the student will be able to

CO1	Examine the concepts of Interference, diffraction, polarisation to solve engineering problems
CO2	Assess the technological applications of lasers and optical fibers
CO3	Apply the quantum mechanical principles for solving engineering problems
CO4	Understand the basics of nanomaterials and their engineering applications
CO5	demonstrate the production, detection and applications of ultrasonics

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	2	-	-	-	-	-	-	-	-	3	2	-	-
CO2	3	3	2	2	-	-	-	-	-	-	-	-	3	2	-	-
CO3	3	3	2	2	-	-	-	-	-	-	-	-	3	2	-	-
CO4	3	3	2	2	-	-	-	-	-	-	-	-	3	2	-	-
CO4	3	3	2	2	-	-	-	-	-	-	-	-	3	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Theory Syllabus

Interference: Principle of Superposition, Coherence and Coherent Sources, Production of Coherent Light, Young's Double Slit Experiment, Concept of interference, Newton's Rings, working of Michelson Interferometer, Fabry-Perot Interferometer, and its application as wavelength filter.

Diffraction: Definition and types of Diffractions, Huygen's Principle and types of wave fronts, types of Diffraction, Single Slit Diffraction, Double Slit Diffraction, Diffraction Grating, Derivation of Resolving Power and Dispersive Power, Rayleigh's Criterion and applications.

Polarization: Introduction to Polarization, Production of Polarized Light by Reflection and Refraction, Phenomenon of Double Refraction, Construction and Working of Nicol's Prism, Half-Wave and Quarter Waveplates, Representation of Different Polarized Lights, Optical Activity, Practical Applications of Polarized Light, Construction and Working of Laurent's Half Shade Polarimeter and Engineering Applications.

Lasers & Optical Fibers: Basic theory of Laser, Fundamentals of lasers, Einstein Coefficients, Characteristics of Laser Pumping Mechanisms; Basic Components of Laser System, 2-Level, 3-Level and 4-Level Systems, Construction and working of He-Ne, Nd-YAG, and semiconductor diode Lasers and Engineering Applications of Lasers. Basic Principle of Optical Fiber, Derivation-Numerical Aperture and Acceptance Angle, Types of Optical Fibers (Step and Graded Index, Single Mode and Multimode), Applications in Communications and Sensors.

Quantum Mechanics: Concepts and experiments that led to the discovery of Quantum Nature, de Broglie hypothesis of matter waves, Heisenberg uncertainty principle, Schrodinger time independent and time

dependent wave equations, the free particle problem, Particle in an infinite and finite potential well, Quantum mechanical tunnelling and applications.

Nanomaterials: Introduction and importance of Nanomaterials, classification (0D, 1D, 2D and 3D) of nanomaterials, properties of nanomaterials, carbon-based nanomaterials, synthesis of nanomaterials, top-down and bottom-up approaches, characterization of nanomaterials, Engineering Applications of Nanomaterials:
Ultrasonics: Production, detection, and applications of ultrasonics

List of Experiments:

1. Determination of Wavelength of Sodium light using Newton's Rings.
2. Determination of Wavelength of He-Ne laser - Metal Scale.
3. Measurement of Width of a narrow slit using He- Ne Laser.
4. Determination of Specific rotation of Cane sugar by Laurent Half-shade Polarimeter.
5. Determination of Numerical aperture, loss, Acceptance angle of optical fiber.
6. Determination of plank constant by photo electric effect.
7. Determination of I – V characteristics of photo diode.
8. Diffraction grating by normal incidence method.
9. Determination of capacitance by using R-C circuit.
10. Determination of resonating frequency and bandwidth by LCR circuit
11. Strain Gauge
12. Dielectric constant measurements
13. Determination of carrier concentration, charge by using Hall effect experiment
14. Study of I-V characteristics of Solar Cell
15. Determination of velocity of ultrasonic waves and adiabatic compressibility of liquids using ultrasonic interferometer.

Learning Resources:

Text Books:

1. Fundamentals of Physics by Halliday, Resnic and Walker, John Wiley, Ninth Edition, 2011.
2. Concepts of Modern Physics by Arthur Beiser, Shobhit Mahajan, S. Rai Choudhury, McGraw Hill Publications, Sixth edition,2009.
3. Engineering Physics by Shatendra Sharma, Jyotnsa Sharma, Pearson Education,2018.
4. Nanotechnology: principles and practices by Sulabha K. Kulkarnl. Springer publications, 3 Ed 2018.
5. Practical Physics by G.L. Squire, Cambridge University press, fourth edition, 2001.

Reference Books:

1. Optics by Ajoy K. Ghatak, Tata McGraw Hill, Sixth Edition, 2017.
2. Understanding Lasers An Entry-Level Guide, by Jeff Hecht, Wiley Publications, Fourth edition,2018.
3. A Textbook of Engineering Physics by M.N. Avadhanulu, P.G. Khirsagar,9th edition,2011.

4. University Physics with modern physics by Hugh D. Young,Roger A. Freedman Pearson Education,2014.
5. Nanotechnology the whole story, -by B. Rogers, J Adams and S. Pennathur, CRC Press. 2013.
6. Engineering Physics Practical by Dr.S.K. Gupta Krishna Prakashan Publications, ninth edition, 2010

Online Resources:

1. https://nptel.ac.in/courses/122/107/122107035/

HS1161 **2-0-2 (3)**

English for Technical Communication

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand and apply principles of technical communication to interact effectively in diverse environments.
CO-2	Analyze complex technical documents to extract and synthesize key information.
CO-3	Employ reported speech, active and passive voice in engineering and scientific contexts to compile technical reports.
CO-4	Demonstrate use of English speech sounds, stress, and intonation in day-to-day situations, conversations, and interactions.
CO-5	Interpret technical data presented in the form of graphs, pie charts, and diagrams.
CO-6	Critique and provide constructive feedback on peer communication performances and written works.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Grammar Principles & Effective Sentence Construction: Correction of Sentences and Concord, - Vocabulary Building, - Synonyms and Antonyms, - Idioms and Phrasal Verbs: Patterns of Use and Suggestions for Effective Employment in Varied Contexts, - Technical Vocabulary (Jargons and Registers),- Strategies for Bringing Variety and Clarity in Sentences, - Removing Ambiguity, - Editing Long Sentences for Brevity and Clarity, - Reported Speech, - Contexts for Use of Reported Speech, - Impact on Audiences and Readers, - Active and Passive Voice, - Reasons for Preference for Passive Voice in Scientific English

Writing- Paragraph & Letter: Definition of Paragraph and Types, - Features of a Good Paragraph, - Unity of Theme, - Coherence, - Linking Devices, - Direction, - Patterns of Development. - Importance in the Context of Other Channels of Communication, - Qualities of Effective Letters, - Types of Letters, - Official Letters, - Letters for Various Purposes, - Letters of Application for Jobs, - Cover Letter and Resume Types, - Letters for Internship/Fellowship, - Writing Statements of Purpose (SOPs), - Examples and Exercises

Reading Techniques:

Definition and Importance, - Skills and Sub-Skills of Reading, - Skimming and Scanning: Uses and Purposes, Examples and Exercises, - Reading Comprehension, - Reading Silently and with Understanding, - Process of Comprehension, - Types of Comprehension Questions

Technical Writing: Principles of a Technical Report, - Know Your Audience, Purpose, and Length of Report, - Understand the Cornerstones of a Presentation, - Define Various Purposes of Presentations and Plan the Correct Structure, - Writing Clear Sentences and Paragraphs, - Removing Jargon, Redundancy, and Wordiness, - Kinds of Graphics and Their Messages, - Suitability for Placement in Graphic Representation, - Introduction to Basic Concepts in Research, - Abstract, Keywords, Methodology, Hypothesis, Plagiarism, Critical Reading, - Abstract Writing, - How to Read Scientific Articles, - Basics of Writing a Research Project Proposal, - Preparation and Presentation of Project Reports

Reviews: Oral and Written Review of a Chosen Novel/Play/Movie, - Review of Scientific Articles and Science Fiction, - Focus on Appropriate Vocabulary and Structure, - Use of Special Vocabulary and Idioms

Language laboratory:

1. **English Sound System** -vowels, consonants, Diphthongs, phonetic symbols- using dictionary to decode phonetic transcription-- Received Pronunciation, its value and relevance- transcription.
2. **Stress and Intonation** –word and sentence stress - their role and importance in spoken English- Intonation in spoken English -definition, -use of intonation in daily life-exercises
3. **Introducing oneself in formal and social contexts** - Role plays. - their uses in developing fluency and communication in general.
4. **Oral presentation** - definition- occasions- structure- qualities of a good presentation with emphasis on body language and use of visual aids.
5. **Listening Comprehension** - Challenges in listening, good listening traits, some standard listening tests- practice and exercises.
6. **Debate/ Group Discussions** - concepts, types, Do's and don'ts- intensive practice, Guided writing practice with examples, Drafting – the mindset to avoid writer's block, Checking your own reports and presentations, Giving and receiving constructive feedback.

Learning Resources:

Text Books:

1. English for Engineers and Technologists (Combined edition, Vol. 1 and 2) Orient Blackswan 2010.
2. Ashraf, M Rizvi. Effective Technical Communication. Tata McGraw-Hill, 2006
3. Meenakshi Raman and Sangeetha Sharma. Technical Communication: Principles and Practice 2nd Edition, Oxford University Press, 2011
4. Tan, Zhongchao. Academic Writing for Engineering Publications: A Guide for Non-native English Speakers. Springer, 2022

Reference Books:

1. Markel, Mike, and Stuart A. Selber. Technical Communication. Bedford/St. Martin's, 2017.
2. Strunk, William, Jr., and E.B. White. The Elements of Style. 4th ed., Longman, 2000.
3. Olsen, Leslie A., and Thomas N. Huckin. Technical Writing and Professional Communication.v2nd ed., McGraw-Hill, 1991.
4. Turabian, Kate L. A Manual for Writers of Research Papers, Theses, and Dissertations. 9th ed., University of Chicago Press, 2018.
5. Seely, John. The Oxford Guide to Writing and Speaking. Oxford University Press, 2004.
6. Murphy, Raymond. English Grammar in Use. 5th ed., Cambridge University Press, 2019.
7. Pinker, Steven. The Sense of Style: The Thinking Person's Guide to Writing in the 21st Century.Viking, 2014.

Reference Books:

1. Zinsser, William. On Writing Well: The Classic Guide to Writing Nonfiction. 7th ed., HarperCollins, 2006.
2. Williams, Joseph M., and Joseph Bizup. Style: Lessons in Clarity and Grace. 12th ed., Pearson, 2016.

3. Einsohn, Amy, and Marilyn Schwartz. The Copyeditor's Handbook: A Guide for Book Publishing and Corporate Communications. 4th ed., University of California Press, 2019.
4. Alley, Michael. The Craft of Scientific Writing. 4th ed., Springer, 2018.
5. Hofmann, Angelika H. Scientific Writing and Communication: Papers, Proposals, and Presentations. 3rd ed., Oxford University Press, 2016.

CS1101 **3-0-0 (3)**

Programming and Data Structures

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design algorithms for solving simple mathematical problems including computing, searching and sorting
CO-2	Compare and contrast algorithms in terms of space and time complexity to solve simple mathematical problems
CO-3	Explore the internals of computing systems to suitably develop efficient algorithms
CO-4	Examine the suitability of data types and structures to solve specific problems
CO-5	Apply control structures to develop modular programs to solve mathematical problems
CO-6	Understand the concept of Abstract Data Types and use in real time applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	1	1	1	2	1	-	-	-	-	-	3	3	3	3	3
CO-2	2	1	2	1	2	3	-	-	-	-	-	3	3	2	2	2
CO-3	1	2	2	2	2	1	-	-	-	-	-	3	3	2	2	1
CO-4	2	2	2	2	2	2	-	-	-	-	-	2	3	2	1	2
CO-5	2	2	3	1	2	2	-	-	-	-	-	2	3	2	2	2
CO-6	2	2	3	2	2	2	-	-	-	-	-	2	3	2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamentals of Computers: Components of a computers, Problems, Flowcharts, Memory, Variables, Values, Instructions, Programs.

Problem solving techniques: Algorithmic approach, characteristics of algorithm, Problem solving strategies: Top-down approach, Bottom-up approach, Number systems and data representation,

Elements of C++ programming language: Data types, constants, and variables, expressions and assignment statements, input and output statements, conditional and branch statements: If-else, Switch-case constructs, iteration statements: while, do-while, for, Arrays – Single and Multi-Dimensional Arrays, strings. Bit-wise operations.

Functions and Recursion: Modular approach for solving real time problems, user defined functions, library functions, parameter passing - call by value, call by reference, return values, passing arrays as parameters to functions Recursion.

Structures and Classes: Declaration, member variables, member functions, access modifiers, function overloading, Problems on Complex numbers, Date, Time, Large Numbers.

Pointers and Files: Introduction to pointers and dynamic allocation, String processing, File operations-create, read and write.

Searching and sorting: Linear and binary search, selection sort, bubble sort, insertion sort, merge sort, quick sort.

Data structures: Abstract Data Types (ADTs) - Stack ADT- Array-Based Implementation of Stack - Applications, Queue ADT - Array-Based Implementation – Applications.

Learning Resources:

Text Books:

1. Walter Savitch, "Problem Solving with C++", Tenth Edition, Pearson, 2018.
2. Cay Horstmann, Timothy Budd, "Big C++", Wiley, 2nd Edition, 2009.
3. R.G. Dromey, "How to solve it by Computer", Pearson, 2008.
4. Mark Allen Weiss, "Data Structures and Algorithm Analysis in C++", Third Edition, Pearson Education, 2006

CS1103 **0-1-2 (2)**

Programming and Data Structures Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design and test programs to solve mathematical and scientific problems
CO-2	Develop and test programs using control structures
CO-3	Implement modular programs using functions
CO-4	Develop programs using classes
CO-5	Develop ADT for stack and queue applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	2	2	1	2	1	-	-	-	-	-	-	3	3	3	3
CO-2	1	1	2	1	2	2	-	-	-	-	-	-	3	3	2	2
CO-3	1	2	3	2	2	1	-	-	-	-	-	-	3	3	2	2
CO-4	2	2	2	2	2	3	-	-	-	-	-	-	2	3	2	1
CO-5	2	2	2	2	2	3	-	-	-	-	-	-	2	3	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

1. Programs on conditional control constructs.
2. Programs on loops (while, do-while, for).
3. Programs using user defined functions and library functions.
4. Programs on arrays, matrices (single and multi-dimensional arrays).
5. Programs using pointers (int pointers, char pointers).
6. Programs on structures.
7. Programs on classes and objects.
8. Programs of Stack and Queue.

Learning Resources:

Text Books:

1. Walter Savitch, "Problem Solving with C++", Ninth Edition, Pearson, 2014.
2. Cay Horstmann, Timothy Budd, "Big C++", Wiley, 2nd Edition, 2009.
3. R.G. Dromey, "How to solve it by Computer", Pearson, 2008.
4. Mark Allen Weiss, "Data Structures and Algorithm Analysis in C++", Third Edition, Pearson Education, 2006

EE1161 **3-0-0 (3)**

Basic Electrical & Electronics Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze DC & AC circuits and determine power & power factor.
CO-2	Understand the specifications of electrical machines.
CO-3	Identify the type of electrical machines for a given application
CO-4	Analyze basic electronic circuits and estimate the illumination requirements.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	2	2	2	2	1	1	1	1	2	1	–	–	–	–
CO-2	3	3	2	2	2	2	1	1	1	1	2	1	–	–	–	–
CO-3	3	3	2	2	2	2	1	1	1	1	2	1	–	–	–	–
CO-4	3	3	2	2	2	2	1	1	1	1	2	1	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

DC Circuits: Kirchhoff's Voltage and Current Laws, Superposition Theorem, Star-Delta Transformations.

AC Circuits: Complex representation of Impedance, Phasor diagrams, Power & Power Factor, Solution of 1-Phase Series & Parallel Circuits.

Single Phase Transformers: Principle of Operation of a Single-Phase Transformer, EMF Equation, Phasor Diagram, Equivalent Circuit of a 1-Phase Transformer, Determination of Equivalent circuit parameters, calculation of Regulation & Efficiency of a Transformer.

DC Machines: Principle of Operation, Classification, EMF and Torque Equations, Characteristics of Generators and Motors. Speed Control Methods.

AC Machines: 3-Phase Induction Motor- Principle of Operation, Torque – Speed Characteristics of 3-Phase Induction Motor & Applications, Principle of Operation of Alternator- EMF equation.

Illumination: Terminology, Laws of illumination and Luminance, Luminaries, LED Lighting (Qualitative).

Electric Heating: Principles of resistance heating, induction heating and dielectric heating. (Qualitative).

Electronic Devices & Circuits: P-type and N-Type semiconductors, P-N junction diode and its I-V characteristics, Single-phase Half-wave and Full wave rectifiers. Bipolar Junction Transistor-operation and CE, CC & CB configurations, Static Characteristics of SCR-MOSFET- IGBT.

Sensors & Transducers: Thermocouple, Thermistor, Resistance Temperature Detector, Hall effect and Piezoelectric Transducers (Qualitative Treatment only)

Electrical Measuring Instruments: Moving Coil & Moving iron ammeters & voltmeters. Wattmeter's (Qualitative).

Electronics Measurements : Principle of Operation of Digital Multi Meter & Cathode Ray Oscilloscope.

Learning Resources:

Text Books:

1. Edward Hughes, Electrical & Electronic Technology, Pearson Education, 2016, 12th Edition.
2. Vincent Del Toro, Electrical Engineering Fundamentals, Pearson Education, 2015, 2nd Edition.
3. V. K Mehtha, Principals of Electrical & Electronics Engineering, S. Chand Publications, New Delhi, 2010, 3rd Edition.
4. V N Mittle and Arvind Mittal, Basic Electrical Engineering, Tata McGraw Hill, 2005, 2nd Edition.

Reference Books:

1. Millman&Halkias, Integrated Electronics - Analog and Digital Circuit and Systems, Tata McGraw-Hill Education, 2017, 2nd edition.
2. U Bakshi& A. Bakshi, Basic Electrical Engineering, Technical Publications, 2019, 2019-Edition.
3. A Fitzgerald, Charles Kingsley, Stephen Umans, Electrical Machines, McGraw Hill Education, 2017, 6th edition.
4. Stephen.J.Chapman, Electric Machinery, McGraw Hill International Edition, 2017, 4th edition.
5. P.S. Bimhbra, Electrical Machinery - Theory, Performance & Applications, Khanna Publishers 2014, 7th edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/108/108108076/

BT1161 **2-0-0 (2)**

Biology for Engineers

Pre-Requisites: **None**

Course Outcomes:

CO-1	Realize the significance of biomolecules for sustaining life
CO-2	Identify the difference between unicellular to multi-cellular organisms
CO-3	Understand heredity, variation and central dogma of life
CO-4	Apply the concepts of biology for engineering the cell

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3
CO-1	3	2	2	–	–	2	2	–	–	2	–	3	3	3	3
CO-2	3	2	2	–	–	2	–	–	–	–	–	3	3	3	3
CO-3	3	2	2	–	–	2	–	–	–	–	–	3	3	3	3
CO-4	3	3	2	2	1	2	2	1	–	2	–	3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Molecules of Life: Chemical basis of life, Proteins, Nucleic acids, Carbohydrates, Lipids, Membranes and First cell, Inside the cell, Cell cycle and Division.

Information processing in living system: Central dogma, Concept of Gene, Genetic code, Transcription, Translation, Biological signal transduction, Quorum sensing and Biofilm formation.

Biomolecular machines and motors: Cytoskeletal motor proteins, ATP synthase, Cell motility.

Applied Biotechnology: Biocomputing, Synthetic biology, Biosensors, Biomedical instrumentation in disease diagnosis, Biomimicry, Biomechanics, Biomaterials, Nanobiotechnology, Industrial and Environmental Biotechnology, Biosafety and Bioethics.

Learning Resources:

Text Books:

1. Quillin, Allison Scott Freeman, Kim Quillin and Lizabeth Allison, Biological Science, Pearson Education India, 2016
2. Reinhard Renneberg, Viola Berkling and Vanya Loroch, Biotechnology for Beginners, Academic Press, 2017

3rd Semester

MM1201 **2-1-0 (3)**

Physical Metallurgy

Pre-Requisites: MM1103

Course Outcomes:

CO-1	Construct phase diagrams based on the given data on binary alloy systems
CO-2	Interpret Fe-Fe_3C phase diagram and other binary phase diagrams
CO-3	Explain theory of diffusion
CO-4	Appraise homogeneous and heterogeneous nucleation
CO-5	Discuss the microstructural aspects of metals and alloys

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	1	1	–	–	–	–	–	–	–	–	–	–	2	–	2
CO-2	3	1	1	–	–	–	–	–	–	–	–	–	–	2	–	2
CO-3	3	1	–	–	–	–	–	–	–	–	–	–	–	1	–	1
CO-4	3	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–
CO-5	3	1	1	–	–	–	–	–	–	–	–	–	–	1	–	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Constitution of Alloys, Construction of equilibrium diagrams, Isomorphous systems, Phase rule, Lever rule, Coring, Miscibility gaps, Eutectic systems, Congruent melting intermediate phases, Eutectoid, Peritectic, Peritectoid, Monotectic and Syntectic reactions. Study of important binary systems - Fe-Fe_3C, Cu-Zn, Al-Cu, etc., Ternary phase diagrams.

Diffusion in Solids: Diffusion mechanisms, Fick's laws of diffusion, Steady state and non-steady state diffusion, Kirkendall effect, Darken's equation, Industrial applications of diffusion processes.

Nucleation Kinetics: Homogeneous nucleation, Rate of homogeneous nucleation, Growth rate equation, Heterogeneous Nucleation, Solidification of pure metal and an alloy, concept of super cooling.

Microstructural Aspects of Metals and Alloys: Optical microscopy, Grain size measurement methods, microstructures of pure metals and alloys.

Learning Resources:

Text Books:

1. S. H. Avner, Introduction of Physical Metallurgy, Mc Graw Hill, 2017, 2nd Edition.
2. V. Raghavan, Physical Metallurgy Principles and Practice, Prentice Hall, New Delhi, 2015, 3rd Edition.
3. V. Raghavan, Materials Science and Engineering, V. Raghavan, Prentice Hall, New Delhi, 2015, 6th Edition.
4. R E. Hill and Abbaschain, Physical Metallurgy Principles, PWS Publishing Company, 2008, 4th Edition.
5. Callister's Materials Science and Engineering, R. Balasubramaniam, Wiley India, 2014, 2nd Edition.

Reference Books:

1. D. S. Clark and W. R. Varney, Physical Metallurgy for Engineers, CBS Publications, New Delhi, 1979, 1st Edition.

Other Suggested Readings:

1. http://www.nptelvideos.in/2012/12/principles-of-physical-metallurgy.html
2. https://nptel.ac.in/courses/113/105/113105023/

MM1203 **3-1-0 (4)**

Metallurgical Thermodynamics

Pre-Requisites: MA1161

Course Outcomes:

CO-1	Explain basic concepts of thermodynamic systems, properties and processes.
CO-2	Apply laws of thermodynamics for calculation of energy requirements of various chemical reactions/processes.
CO-3	Decide feasibility of thermodynamic reactions using thermodynamics potentials.
CO-4	Estimate partial molar quantities, thermodynamic properties of solutions and solubility of gases during preparation of solutions.
CO-5	Evaluate thermodynamic properties from electrode potentials of various reactions in electro-chemical cells.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	2	2	2	2	–	–	–	–	–	–	–	1	1	–	–
CO-2	3	2	2	2	2	–	–	–	–	–	–	–	3	3	–	–
CO-3	3	2	2	2	2	–	–	–	–	–	–	–	3	3	–	–
CO-4	3	2	2	2	2	–	–	–	–	–	–	–	1	2	–	–
CO-5	3	2	2	2	2	–	–	–	–	–	–	–	2	2	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction and Basic Principles: First Law of Thermodynamics, enthalpy, heat capacities, Hess's law, Kirchhoff's equation; Second Law of Thermodynamics and Entropy, Combined expression of I and II laws, Thermodynamic equation of state, Relation between Cp and Cv; Application of thermodynamic equation of state.

Free Energy Functions and their significance: Gibbs-Helmholtz and Maxwell equations; Third Law of Thermodynamics and applications; Clausius-Clapeyron Equation: Derivation of Clausius-Clapeyron equation and its Integration; Ramsay-Young, Trouton's and Duhring's rules; Fugacity, Activity and Equilibrium Constant, Numerical calculations involving equilibrium constant; Variation of equilibrium constant with temperature, Integration of free-energy equation, Sigma function; Concept of Chemical potential and Gibbs Phase Rule.

Thermodynamics of Solutions: Concept of partial molar quantities, Gibbs-Duhem equation, Determination of PMQs, Free energy of formation of binary solutions; Raoult's law; concept of activity coefficient; Henry's law and Sievert's law; Integration of Gibbs-Duhem equation, The α function, and Excess thermodynamic quantities.

Thermodynamics of electro-chemical cells: Galvanic cells, relation between chemical and electrical energy; Standard emf of a cell, reversible electrode potential, sign convention and standard potentials of metals; Application of Gibbs-Helmholtz equation to galvanic cells; Concentration cells, Applications of emf cells.

Learning Resources:

Text Books:

1. Introduction to the Thermodynamics of Materials, David R. Gaskell and David E. Laughlin, CRC Press, Taylor and Francis Group, 2017, 6th Edition.
2. Principles of Metallurgical Thermodynamics, S. K. Bose and S. K. Roy, Universities Press-IIM series in Metallurgy and Materials Science, 2014.
3. Chemical and Metallurgical Thermodynamics, M. L. Kapoor, Vol. 1 - Fundamentals (1981) & Vol. 2-Applications (1984), NEM CHAND & BORS; Roorkee.
4. Physical Chemistry for Metallurgists, J. Mackowiak, © George Allen & Unwin Ltd., PITMAN PRESS, BATH, 1966.
5. Physical Chemistry of Metals, Lawrence S. Darken & Robert W. Gurry, CBS Publishers & Distributors-Delhi, 1953.

Reference Books:

1. Text Book of Materials and Metallurgical Thermodynamics, Ahindra Ghosh, Prentice Hall of India Pvt. Ltd., 2003.
2. Stoichiometry and Thermodynamics of Metallurgical Processes, Y. K. Rao, Cambridge Univ. Press, 1985.
3. Problems in Metallurgical Thermodynamics and Kinetics, G. S. Upadhyaya and R. K Dube, Pergamon, NewYork, 1982.
4. Thermodynamics- N. A. Gokcen and R. G. Reddy, Plenum Press – New York & London, 1996, Second Edition.
5. Chemical Metallurgy, J. J. Moore, Butterworth- Heinemann, 1994.

Other Suggested Readings:

1. Chemical Thermodynamics of Materials by C.H.P. Lupis
2. Chemical Thermodynamics of Materials - Macroscopic and Microscopic Aspects by Svein Stølen, Tor Grande, Neil L. Allan, John Wiley & Sons Ltd., 2004
3. Thermodynamics of Solids by R.A. Swalin
4. Chemical Thermodynamics for Metals and Materials by Hae-Geon-Lee, Imperial College Press, 2000
5. NPTEL Courses, MIT Open Course Ware, etc.

MM1205 **3-0-0 (3)**

Unit Processes in Extractive Metallurgy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss basic unit processes used for metals extraction.
CO-2	Apply Ellingham diagrams and basic thermodynamic principles for extraction of metals.
CO-3	Summarize unit processes and principles employed in pyro-, hydro- and electro- metallurgy for mineral beneficiation, refinement, and metal extraction.
CO-4	Explain reaction kinetics, heat & material balance and process flow sheets for the extraction of non-ferrous metals.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	3	2	-	-
CO-2	3	3	-	-	-	-	-	-	-	-	-	1	2	3	-	-
CO-3	3	-	1	-	-	1	1	-	-	1	-	-	2	2	-	-
CO-4	3	3	1	-	-	1	1	-	-	2	-	2	3	3	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Occurrence of metals in nature, minerals versus ores. Overview of metallurgical thermodynamics relevant to metals extraction – laws of thermodynamics, state vs path functions, thermochemistry, inter-relationships between state variables, Solution thermodynamics, Reaction thermodynamics.

Pyrometallurgy: Drying and calcination, roasting and derivation of roasting conditions by Kellog's diagrams (predominance area diagrams), relevance of Ellingham diagram in metal extraction, smelting and converting, metal refining processes - fire-refining, liquation, and distillation.

Hydro- & electrometallurgy: Leaching and its methods, construction, and use of Pourbaix diagram, bioleaching, solution purification and concentration. Recovery of metals from leach solutions, introduction to electrochemistry & electrolytic systems, Principles of electrolysis, electro-refining, electro-winning and other electrometallurgical processes.

Reaction Kinetics and Process Flow Sheets: Reaction kinetics, heat and materials balance, illustration of metal extraction flowsheets for various metals, Production of iron and steel, aluminum, copper, zinc, and lead. Analysis of unit processes: Reactor kinetics, heat and material balance.

Learning Resources:

Textbooks:

1. Terkel Rosenqvist, Principles of Extractive Metallurgy, 2nd ed., McGraw Hill, 1983.
2. H. S. Ray, R. Sridhar and K.P. Abraham, Extraction of Non-ferrous Metals, Affiliated East West, 1985.

Reference Books:

1. F. Habashi, Principles of Extractive Metallurgy, Vol. 1-4, McGraw-Hill, 1993.
2. C. K. Gupta, Chemical Metallurgy: Principles and Practice, John Wiley & Sons, 2006.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/105/113105021/

MM1207

3-1-0 (4)

Transport Phenomena

Pre-Requisites: MA1161

Course Outcomes:

CO-1	Discuss transport properties of fluids and solids
CO-2	Apply mass and momentum transfer principles in the extraction and refining of metals.
CO-3	Apply the heat transfer principles in furnace design and heat treatment of materials.
CO-4	Calculate material and energy balances in material flow systems.
CO-5	Illustrate simultaneous momentum, heat and mass transfer in metallurgical reactions.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-2	3	2	1	–	–	–	–	–	–	–	–	–	3	2	–	–
CO-3	3	2	1	–	–	–	–	–	–	–	–	–	2	2	–	–
CO-4	3	2	1	–	–	–	–	–	–	–	–	–	2	–	–	–
CO-5	3	2	1	–	–	–	–	–	–	–	–	–	3	2	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Newton's law of viscosity, Molecular theory of viscosity of gas/liquid, Types of fluid flow, Reynolds experiments, Equation of continuity and motion, Momentum transfer in fluid, Shell momentum balance and velocity profile, concept of velocity boundary layer, Navier stokes equation and its applications, flow past submerged bodies, fluid flow in packed bed, Law of conservation of energy, Bernoulli's equation, Friction in pipes and channels, fans, pumps, blowers, compressors, fan laws.

Fourier's law of heat conduction in solids, conduction in liquids and gases, steady state and unsteady state conduction in solids, Natural convection, forced convection, concept of heat transfer coefficient and thermal boundary layer, Radiation heat transfer, Gurney-Lurie, Haisler, Hottel and allied charts. Heat transfer with change of phase. Introduction to solidification heat transfer and ablation, Heat transfer in packed and fluid beds.

Diffusivity and steady state diffusion, Darken's equation, Kirkendall's effect, Unsteady state mass transfer, concept of mass transfer coefficient concentration boundary layer, Inter-phase mass transfer –theories, introduction to simultaneous mass and heat transfer. Classification of diffusional operations and conduction of diffusional operations. Similarity criteria and introduction to model and pilot plant studies, Similarities of momentum, mass and energy transfer.

Learning Resources:

Text Books:

1. G. H. Geiger, D. R. Poirier, Transport Phenomena in Materials Processing, John Wiley & Sons, 2010

2. A. K. Mohanty, Rate Processes in Metallurgy, PHI, 2012
3. R.B. Bird, Stewart and Lightfoot, Transport Phenomena, 2nd Wiley 2021

Reference Books:

1. David R Gaskell, An Introduction to Transport Phenomena in Materials Engineering, Momentum Press, 2013
2. Sujay Kumar Datta, Fundamental of Transport Phenomena and Metallurgical Process Modelling, Springer, 2023
3. N J Themelis, Transport and Chemical Rate Phenomena, Routledge, 2004
4. R. B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena 2ed., Wiley- India, 2021
5. Julian Szekely, Fluid Flow Phenomena in Metals Processing, Academic Press Inc., 1980
6. F P Incropera, D P David, T L Bergman, A S Lavine, Principles of Heat and Mass Transfer, Wiley, 2019

Other Suggested Readings:

1. https://nptel.ac.in/courses/112106237
2. https://ocw.mit.edu/courses/3-185-transport-phenomena-in-materials-engineering-fall-2003/

MM1209 **3-0-0 (3)**

Electronic and Magnetic Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the principles, applications, and industrial processing of magnetic materials.
CO-2	Design microstructures for enhanced properties of hard and soft magnets.
CO-3	Describe the principles, industrial processing, and structure of semiconducting materials.
CO-4	Discuss the principles, synthesis, and structure of superconducting materials.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	1	-	2	-	1	-	-	-	-	-	1	2	1	-	-
CO-2	2	3	3	3	-		-	-	-	-	-	2	2	3	-	2
CO-3	2	2	2	1	-	1	-	3	2	2	-	1	3	1	2	1
CO-4	2	2	2	1	-	1	-	-	-	-	-	1	2	1	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Magnetic Materials: Principles of magnetism; Classification of magnetic materials; Processing, properties, and structure of hard magnets: hard ferrites, AlNiCo, and rare-earth magnetic materials; and soft magnets: soft ferrites, Finemet, and metallic glasses; Recent advances.

Semiconducting Materials: Basic semiconductor principles; Processing of metallurgical and electronic grades of silicon, Growth of single crystals and wafer preparation; Physical vapour deposition and chemical vapour deposition; Lithography; Photovoltaics; Light emitting diodes (LEDs); Recent advances.

Superconducting Materials: BCS theory, Type I and II superconductors, Meissner Effect; Processing, properties, and structure of high-temperature superconducting materials: YBCO & Bi-2212; Recent advances.

Learning Resources:

Text Books:

1. B. D. Cullity, C.D. Graham, 2nd Ed., Introduction to Magnetic Materials, Wiley and IEEE, 2009
2. J D Patterson, Solid State Physics, 2nd Edition, Springer, 2011.
3. D.M. Hoffman, B. Singh, J.H. Thomas, Handbook of Vacuum Science and Technology, Academic Press 1998.
4. David Jiles, Introduction to Magnetism & Magnetic Materials, London: Chapman & Hall, 1998.
5. Milton Ohring, Materials Science of Thin Films, Academic Press, San Diego, 2002.

Reference Books:

1. John J. Croat, Rapidly Solidified Neodymium-Iron-Boron Permanent Magnets, Woodhead Publishing, 2017
2. G.S. May and C.J. Spanos, Fundamentals of Semiconductor Manufacturing and Process Control, Wiley – IEEE, 2006.

Other Suggested Readings:

1. NPTEL Courses: https://nptel.ac.in/courses/113/106/113106065/

MM1211 **0-1-2 (2)**

Physical Metallurgy and Metallography Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Appraise the atomic packing efficiency, linear and planar densities by constructing crystal structure models
CO-2	Prepare metallic samples for microstructural observation
CO-3	Examine the microstructures of ferrous and non-ferrous alloy samples
CO-4	Distinguish the microstructures of steels and cast irons
CO-5	Determine the grain size and volume fractions of phases in the given microstructure

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	1	–	–	–	–	–	–	2	–	–	–	–	–	–	–
CO-2	2	–	–	–	2	1	–	–	2	3	–	–	–	2	–	2
CO-3	2	1	–	–	2	–	–	–	–	3	–	–	–	2	–	1
CO-4	2	1	–	–	2	–	–	–	–	3	–	–	–	2	–	1
CO-5	2	1	–	–	2	–	–	–	–	3	–	–	–	2	–	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Following is the list of experiments:

1. Preparation and study of crystal structure models
2. Study the working principle and operation of metallurgical microscope
3. Cold and hot mounting of specimens
4. Specimen preparation for metallographic observation
5. Study the Fe-Fe_3C phase diagram
6. Microstructural analysis of low, medium and high carbon steels
7. Microstructural analysis of cast-iron specimens
8. Microstructural analysis of non-ferrous alloys
9. Study the methods of grain size determination
10. Quantitative metallography of two-phase microstructures

Learning Resources:

Text Books:

1. Physical Metallurgy Laboratory Manual
2. George F. Vander Voort, Metallography Principles and Practice, ASM International, 1999.

Reference Books:

1. George F Vander Voort, Metallography and Microstructures, ASM Handbook Volume 9, (Ed.), ASM International, 2004
2. D. S. Clark and W. R. Varney, Physical Metallurgy for Engineers, CBS Publications, New Delhi, 1979, 1st Edition.

3. S. H. Avner, Introduction of Physical Metallurgy, Mc Graw Hill, 1987, 2nd Edition.
4. R. Balasubramaniam, Callister's Materials Science and Engineering, Wiley India, 2014, 2nd Edition.

Other Suggested Readings:

1. https://www.doitpoms.ac.uk/miclib/index.php
2. http://vlabs.iitb.ac.in/vlabs-dev/labs/nitk_labs/physical-metallurgy/labs/index.php

MM1213 **0-1-2 (2)**

Unit Processes in Extractive Metallurgy Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Carry out suitable unit process for extraction of metals.
CO-2	Perform suitable concentration technique for leach solution.
CO-3	Carryout electro deposition of metals.
CO-4	Identify techniques for recovery of metals from leach solutions.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	-	-	-	3	-	-	-	1	1	1	1	2	3	-	-
CO-2	2	-	-	-	3	1	1	-	1	1	-	1	2	3	-	-
CO-3	2	-	-	-	3	-	-	-	1	1	-	-	2	2	-	-
CO-4	2	-	-	-	3	1	1	-	1	1	1	1	2	3	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Sampling and Sieve analysis, Comminution: Crushing and Grinding, Verification of Stoke's law, Calcination, Oxidising Roasting, Reduction of oxide, Cementation, Electrolysis to deposit Ni and Cr, Effect of cathodic current density and throwing power on electroplating process, Leaching of ores, Anodising, Solvent Extraction, Electroless plating.

Learning Resources:

Text Books:

1. M. Shamsuddin, Physical Chemistry of Metallurgical Processes, Wiley, 2016.
2. R.D. Pehlke, Unit Processes in Extractive Metallurgy, Elsevier, 1973.

Reference Books:

1. Extractive Metallurgy 2 & 3: Alain Vignes, Wiley-Iste, 2011.
2. F. Habashi, Principles of Extractive Metallurgy, Vol. 1-4, McGraw-Hill, 1993.

4th Semester

MA1263 **3-0-0 (3)**

Partial Differential Equations, Statistics and Numerical Methods

Pre-requisites: **MA1262**

Course Outcomes:

CO-1	Determine the solution of a PDE by variable separable method
CO-2	Interpret an experimental data using interpolation / curve fitting
CO-3	Solve algebraic/transcendental equations and ordinary differential equations
CO-4	Understand the concepts of probability and statistics
CO-5	Perform testing of hypothesis

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-2	3	2	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-3	2	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-4	3	2	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-5	3	3	1	3	1	–	–	–	–	–	–	–	–	1	2	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Partial Differential Equations: Introduction to Fourier series (including half range), Method of separation of variables - Solution of one-dimensional wave equation, one dimensional heat conduction equation.

Numerical Methods: Gauss-Seidal iteration method to solve a system of equations - Numerical solution of algebraic and transcendental equations by Regula-Falsi method and Newton-Raphson's method - Lagrange interpolation, Forward and backward differences, Newton's forward and backward interpolation formulae - Numerical differentiation with forward and backward differences - Numerical Integration with Trapezoidal rule, Simpson's 1/3 rule and Simpson's 3/8 rule - Taylor series method, Euler's method, 4th order Runge-Kutta method for solving first order ordinary differential equations

Probability and Statistics: Random variables, discrete and continuous random variables, Mean and variance of Binomial, Poisson and Normal distributions and applications. Testing of Hypothesis – Null and alternate hypothesis, level of significance and critical region - Z-test for single mean and difference of means, t-test for single mean and difference of means - F-test for comparison of variances.

Learning Resources:

Text Books:

1. Advanced Engineering Mathematics, R. K. Jain and S. R. K. Iyengar, Narosa Publishing House, 2016, Fifth Edition.
2. Advanced Engineering Mathematics, Erwin Kreyszig, John Wiley and Sons, 2015, Tenth Edition

Reference Books:

1. Miller & Freund's Probability and Statistics for Engineers, Richard A. Johnson, Pearson, 2018, Ninth Edition.
2. Advanced Engineering Mathematics, Dennis G. Zill, Jones & Bartlett Learning, 2018, Sixth Edition
3. Higher Engineering Mathematics, B. S. Grewal, Khanna Publishers, 2012, Forty-second Edition.

MM1202 **3-1-0 (4)**

Phase Transformations and Heat Treatment

Pre-Requisites: MM1103, MM1201

Course Outcomes:

CO-1	Explain the concepts of phase transformations in metals and alloys.
CO-2	Apply TTT and CCT diagrams to interpret microstructural development in steels.
CO-3	Discuss industrial heat treatment techniques to engineer microstructure for optimization of mechanical properties in metals and alloys.
CO-4	Apply surface modification concepts for betterment of industrial components

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	1	3	–	–
CO-2	3	–	3	–	–	–	–	–	–	–	–	–	–	3	–	–
CO-3	3	–	3	–	–	–	–	–	–	–	–	–	–	3	–	–
CO-4	3	–	3	–	–	–	–	–	–	–	–	–	–	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Phase Transformations: Phase Transformations of Materials, Application of Nucleation and Growth concept in Phase Transformation, Study of Fe-Fe_3C phase diagram, Phase transformation of Steel, Austenite Grain Growth, Determination of Austenite Grain Size, Isothermal Transformation Diagrams, Pearlite, Bainite and Martensite Transformation, TTT and CCT Plots.

Heat Treatment: Annealing, Normalising, Hardening, Tempering, Quenching Media, Quench Cracks, Martempering, Austempering, Hardenability, Cast Iron, Malleabilisation, ADI, Heat Treatment of HSLA, Tool Steels, Hadfield Mn Steel, Stainless Steel, and Age Hardening, Case Hardening, Quality control in Heat Treatment Industries.

Learning Resources:

Text Books:

1. Y. Lakhtin, Engineering Physical Metallurgy, Mir Publisher, 2005, 2nd Edition.
2. D. A. Porter and K. E. Easterling, Phase Transformation in Metals and Alloys, VNR International, 1992, 1st Edition.

Reference Books:

1. S. H. Avner, Introduction to Physical Metallurgy, McGraw Hill Education, 2017, 2nd Edition.
2. Callister, Materials Science and Engineering, Wiley India, 2014, 2nd Edition.

MM1204 **3-1-0 (4)**

Ferrous Extractive Metallurgy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the raw materials requirement of iron extraction and steel making
CO-2	Explain physico-chemical processes of iron extraction and hot metal refinement
CO-3	Discuss the open hearth, Bessemer, LD and Q-BOP steel making processes
CO-4	Describe alternate routes of iron making and secondary steel-refining techniques
CO-5	Discuss the practice of the ingot and continuous casting of steel

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	3	3	–	–
CO-2	3	–	–	–	–	–	–	–	–	–	–	–	3	2	–	–
CO-3	3	–	–	–	–	–	–	–	–	–	–	–	3	2	–	–
CO-4	3	–	–	–	–	–	–	–	–	–	–	–	3	2	–	–
CO-5	3	–	–	–	–	–	–	–	–	–	–	–	3	2	–	–
CO-6	3	–	–	–	–	–	–	–	–	–	–	–	3	2	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

History of Ironmaking: Importance of Iron and Steel for the modern society. Burden materials: Iron ore deposits in India and the world. Metallurgical coal, Limestone and Dolomite, Coke: functions, quality requirements. Ore agglomeration techniques.

Blast Furnace principles and operation: Construction of blast furnace and its accessories, Thermal, physical and chemical profiles, thermodynamics and kinetics of iron oxide reduction. Reactions at various zones. Blowing in, banking, blowing out, tapping, fanning, back drafting. Irregularities in blast furnace. Burden distribution. Modern trends in Blast furnace. Alternate routes of iron production: Furnace design developments, Sponge iron production, Smelting reduction processes.

Steelmaking: Thermodynamics and kinetics in steelmaking. Conventional steelmaking practices: Bessemer process and open-hearth process. Modern steelmaking practices: Basic oxygen steelmaking processes. Secondary steelmaking processes: Deoxidation process, ladle metallurgy, injection metallurgy, VAR & ESR processes, etc., Ingot casting process, and continuous casting process.

Learning Resources:

Text Books:

1. Ahindra Ghosh & Amit Chatterjee, Iron Making and Steel Making- Theory and Practice, Prentice-Hall of India Pvt. Ltd, 2008.
2. R.H. Tupkary, V.R. Tupkary, Modern Iron making handbook, MLI Handbook Series, 2017.
3. A. K. Chakrabarti, Steel Making, PHI Learning Pvt. Ltd., NewDlehi, 2007.
4. Ahindra Ghosh, Secondary Steel Making- Principles and Applications, CRC Press, 2001.

Reference Books:

1. C. Bodsworth, Physical Chemistry of Iron and Steel manufacture, Metallurgy and Metallurgical Engineering Series, 2014.
2. F. Habashi, Principles of Extractive Metallurgy, Vol. 1-4, McGraw-Hill, 1993.

Other Suggested Readings:

1. NPTEL: steelmaking by Prof. Satish Ch. Koria (http://nptel.ac.in/courses/113104013/)
2. steeluniversity.org

MM1206 **3-0-0 (3)**

Casting and Solidification Processing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the principles of solidification in metals and alloys.
CO-2	Correlate the morpho-genesis of solidification microstructures with the heat and mass transfer conditions.
CO-3	Describe the casting techniques.
CO-4	Design the gating and risering of castings.
CO-5	Identify the melting furnaces for metals and alloys.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-4	3	2	2	2	-	-	-	-	-	-	-	-	3	-	-	1
Co-5	3	2	-	-	-	-	-	-	-	-	-	-	-	-	2	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Thermodynamics of solidification: pure metal solidification i.e. G vs T curves for liquid and solid, alloy solidification.

Scheil equation: Mathematical analysis of redistribution of solute during directional solidification, Micro segregation, Constitutional undercooling.

Theories of nucleation and growth: Mullins-Sekarka instability, Ivantsov theory of dendritic growth. Multi-phase solidification: regular and irregular eutectic solidification, Hunt-Jackson theory of eutectic growth, peritectic growth, Structure of casting and ingots.

Casting Techniques: Types of casting, Heat transfer, design of riser and gating. Solidification, heat transfer, fluid flow during fusion welding. Casting Defects. Melting furnaces.

Case Studies: Melting and solidification of cast irons and aluminum. Solidification, heat transfer and fluid flow during fusion welding.

Learning Resources:

Text Books:

1. Kurz and Fisher, Solidification Processing, Trans Tech publications 1998.
2. R. W. Heine, C. R. Loper, P. C. Rosenthal, Principles of metal casting, Mc Graw Higher Ed, 1976.
3. K. Easterling, Introduction to physical metallurgy of welding, Butterworth-Hienemann 1992.
4. P. K. Jain, Principles of foundry technology, Mc Graw-Hill 1987.

MM1208 **3-0-0 (3)**

Ceramics and Composites Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	State the properties and applications of metals, ceramics, polymers, and composites.
CO-2	Describe the processing routes of ceramics and composites
CO-3	Apply the rule of mixtures to estimate the properties of composites
CO-4	Explain the strengthening mechanisms in composites
CO-5	Select suitable ceramics and composite materials for a particular application

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-2	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-3	3	–	–	2	–	–	–	–	–	–	–	–	–	–	–	3
CO-4	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-5	3	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Ceramics: Introduction to ceramics, general properties of ceramics and applications. Crystal structure, bonding in ceramics, defects in ceramics structures, classification of ceramics-oxides ceramics, nonoxide ceramics, production of ceramic powders through various techniques. Fabrication of ceramics, porous ceramics, glasses, glass ceramics, super plasticity in ceramics, bio ceramics, creep mechanism in ceramics, toughening mechanism in ceramics.

Composites: Introduction to Composites, properties and applications. Rule of mixture calculations, classification of composites based on matrix materials: metal matrix-, ceramic matrix-, and polymer matrix-composites. Classification of composites based on reinforcements: particulate reinforced, fibre reinforced composites, hybrid composites, Fabrication of composites, fracture behaviour of composites, Case studies.

Learning Resources:

Text Books:

1. W. David Kingery, H. K. Bowen and Donald R. Uhlmann, Introduction to Ceramics, John Wiley & Sons, 2004, 2nd Edition.
2. Deborah D. L. Chung, Composite Materials: Science and Applications, Springer, 2009, 2nd Edition.
3. F.L. Matthews and R.D. Rawlings, Composite Materials: Engineering and Science, CRC Press, 1999.
4. Krishan Kumar Chawla, Composite Materials- Science and Engineering, Springer, 2012

Reference Books:

1. B. Raymond, Seymour and Charles E. Carraher Jr., An Introduction to Polymers, Dekkar Inc. New York, 1987, 2nd Edition
2. D. Hull, T.W. Clyne, An Introduction to Composite Materials, Cambridge University Press, New York, 1996, 2nd edition
3. Michel Barsoum and M.W. Barsoum, Fundamentals of Ceramics (Series in Materials Science and Engineering) 2002.

Other Suggested Readings:

1. https://nptel.ac.in/content/storage2/courses/101104010/downloads/Lecture4.pdf
2. https://www.youtube.com/watch?v=7Be7hGvqoAg
3. https://youtu.be/0kB0G6WKhKE?list=PLSGws_74K01-bdEEUElQ9-obrujIKGEhg

MM1210 **0-1-2 (2)**

Phase Transformations and Heat Treatment Laboratory

Pre-Requisites: MM1201

Course Outcomes:

CO-1	Practice industrial heat treatment processes for ferrous and nonferrous alloys
CO-2	Observe microstructure using optical and scanning electron microscopes
CO-3	Evaluate the hardenability of steels by Jominy end quench test.
CO-4	Conduct microstructure-property correlation of heat-treated samples

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	2	–	–	–	–	2	–	–	1	3	–	–
CO-2	–	–	2	–	2	–	–	–	–	2	–	–	–	3	1	–
CO-3	3	–	2	–	2	–	–	–	–	2	–	–	–		2	–
CO-4	–	–	2	–	2	–	–	–	–	2	–	–	–		1	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Grain size measurement & Calculation of Volume fraction of Phases, Microstructure of Steels and Composites, Microstructure of Annealed, Normalising, Hardened samples, Tempering, Jominy End Quench Test and Scanning Electron Microscopy (SEM) Study of Different Samples

Learning **Resources:**

Text Books:

1. S. H. Avner, Introduction to Physical Metallurgy, McGraw Hill Education, 2017, 2nd Edition.
2. Alloy Phase Diagrams, ASM Handbook, Volume 3.

.

Other Suggested Readings:

1. NPTEL Courses
2. MIT Open Course Ware, etc.

MM1212 **0-1-2 (2)**

Solidification Processing Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Determine moulding sand properties.
CO-2	Demonstrate the preparation of moulds.
CO-3	Demonstrate melting practice.
CO-4	Demonstrate casting of metals/alloys.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	-	-	-	3	3	-	-	-	-	2	-	-	1	-	-	3
CO-2	-	-	-	-	3	-	-	-	3	2	-	-	3	-	-	-
CO-3	-	-	-	-	3	-	-	-	3	2	-	-	3	-	-	-
CO-4	-	-	-	-	3	-	-	-	3	2	-	-	3	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Sand Testing: Green and dry strength testing, Determination of permeability, Shatter index, clay content, Moisture content, cured transverse strength of shell sands. Mould preparation. Demonstration of Melting and casting: Casting of metals using induction furnace, casting of metals using vacuum arc melting furnace, casting of metals using resistance heating furnace.

Learning Resources:

Text Books:

1. Solidification Processing, Kurz and Fisher, Trans Tech publications 1998.
2. Principles of metal casting, R. W. Heine, C. R. Loper, P. C. Rosenthal, Mc Graw Higher Ed, 1976.
3. Introduction to physical metallurgy of welding, K. Easterling, Butterworth-Hienemann 1992.
4. Principles of foundry technology, P. K. Jain, Mc Graw-Hill 1987.

5th Semester

MS1262 **3-0-0 (3)**

Business Essentials for Engineers

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic concepts of management and its functions
CO-2	Apply the functions of management for taking effective decisions.
CO-3	Analyze factors influencing management in competitive business environment
CO-4	Identify business opportunities and challenges
CO-5	Integrate functions of management for building a better organization.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	–	–	–	–	–	–	–	–	3	–	3	3	–	–	–	–
CO-2	–	–	–	–	–	–	–	–	2	–	3	3	–	–	–	–
CO-3	–	–	–	–	–	–	–	–	1	–	3	3	–	–	–	–
CO-4	–	–	–	–	–	–	–	–	1	–	2	2	–	–	–	–
CO-5	–	–	–	–	–	–	–	–	1	–	1	2	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: The evolution of management theory, Business functions and their roles, Organizations and types, Levels of management, Types of markets and pillars of management- planning, organizing, leading and controlling.

People Management: Catalysts for organizational performance – Motivation & Leadership, Organization culture & Change, Human resource functions in a dynamic business environment and evolving dynamics in Industrial Relations.

Marketing Management: Nature and scope of marketing, Company's orientation towards market place, Importance of marketing concept, Marketing environment, 4p's of marketing, market segmentation, target market selection and positioning.

Financial Management: Financial accounting, Financial statements and analysis for decisions, Financial planning, Capital, Working capital, Capital structure and Sources of corporate finance, Investment decisions.

Quality & Strategy: Quality, Principles, Quality Awards, Standards of Quality culture, Quality metrics programs, Strategy, Vision and Mission, Porter's 5–forces, McKinsey's 7S Model, BCG Matrix, Competitive advantage - Value chain analysis & Resource based view.

Learning Resources:

Text Books:

1. Ronald J. Ebert, Ricky W. Griffin, Business Essentials, Pearson, 2019, 12th Edition

2. Harold Koontz, Heinz Weihrich, Mark V. Cannice, Essentials of Management, McGraw hill, 2020, 11th Edition

Reference Books:

1. G. Shainesh Philip Kotler, Kevin lane Keller, Alexander Chernev, Jagdish N. Sheth, Marketing Management, Pearson, 2022, 16th Edition
2. Dessler, G., & Varkkey, B, Human Resource Management, Pearson Education, 2024, 17th Edition
3. Prasanna Chandra, Financial Management: Theory & Practice, Mc Graw Hill, 2022, 11th Edition.
4. Poornima M Charantimath, Total Quality Management, Pearson, 2022, 4th Edition.
5. IM Pandey, Financial Management, Vikas Publications, 2021, 12th Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/110106050
2. https://nptel.ac.in/courses/110105146
3. https://nptel.ac.in/courses/110105069
4. https://nptel.ac.in/courses/110104068
5. https://ocw.mit.edu/courses/15-535-business-analysis-using-financial-statements-spring-2003/
6. https://ocw.mit.edu/courses/15-810-marketing-management-fall-2010/

MM1301 **3-0-2 (4)**

Corrosion Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the principles of corrosion.
CO-2	Evaluate corrosion mechanisms from first principles.
CO-3	Suggest suitable techniques for corrosion monitoring and its prevention.
CO-4	Discuss the mechanism of high temperature oxidation.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–
CO-2	2	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–
CO-3	2	2	–	–	2	–	–	–	–	–	–	–	–	2	–	–
CO-4	3	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Principles of Corrosion: Introduction, Corrosion rate expressions, Thermodynamics of corrosion, Forms of Corrosion, Pourbaix diagrams, Corrosion Prevention and High Temperature Corrosion.

Modern Theory: Electrode kinetics, Exchange current density, Activation polarization, Concentration polarization, combined polarization, mixed electrode-potential Theory, Passivity, Tafel extrapolation, Linear Polarization, Electrochemical Impedance Spectroscopy.

Learning Resources:

Text Books:

1. M G Fontana, N D Greene, Corrosion Engineering, McGraw Hill, New York, 1967.
2. Nestor Perez, Electrochemistry and Corrosion Science, Kluwer, 2004.
3. Zaki Ahamad, Principles of Corrosion Engineering and Corrosion Control, Elsevier, 2006.

Reference Books:

1. ASM Metal Handbook, Vol 13A- Corrosion- Fundamentals, Testing & Protection, ASM, 2004.
2. Shreir's Corrosion, Four Volumes, Elsevier Science, 2010.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/104/113104082/ (Corrosion I and II, Prof. Kallol Mondal, IIT Kanpur).

MM1303 **3-0-0 (3)**

Powder Metallurgy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain powder production technique
CO-2	Describe the characterization techniques of the metal powders
CO-3	Discuss powder shaping techniques
CO-4	Explain the stages of sintering and influence of sintering atmospheres
CO-5	Discuss case studies on processing of industrial components

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	2	–	1	–
CO-2	3	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2
CO-3	3	–	–	–	–	–	–	–	–	–	–	–	3	–	1	–
CO-4	3	2	2	–	–	–	–	–	–	–	–	–	3	2	–	–
CO-5	3	–	–	3	–	–	–	–	–	3	–	3	2	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Powder Production and Characterization: Mechanical and Chemical methods, Mechanical Alloying, Atomization, Characterization of Particle Size and Shape, Electron Microscopy of Powder, Interparticle Friction, Compressibility, Chemical Characterization. Microstructure Control of Powder

Powder Shaping and Sintering: Particle Packing, Lubricants /Binders, Powder Compaction & Process Variables, Isostatic Pressing, Injection Molding, Powder Extrusion, Slip Casting, Tape Casting, additive manufacturing of Ceramics, Sintering theory, Liquid Phase Sintering, Sintering Variables, Modern Sintering, PM of Filters, Tungsten Filaments, Self-Lubricating Bearings, Porous Materials, ODS Alloys, Biomaterials etc.

Learning Resources:

Text Books:

1. R. M. German, Powder Metallurgy & Particulate Materials Processing, MPIF, 2005, 3rd Edition.
2. Upadhyaya and G S Upadhyaya, Powder Metallurgy, Universities Press, 2011, 1st Edition.

Reference Books:

1. P. C. Angelo and R. Subramanian: Powder Metallurgy- Science, Technology and Applications, PHI, 2008, 1st Edition.
2. J. S. Hirschhorn: Introduction to Powder Metallurgy, American Powder Metallurgy Institute, 1976, 1st Edition

MM1305 **2-1-0 (3)**

Mechanical Metallurgy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the theories of elastic and plastic behaviour of materials
CO-2	Differentiate mechanical testing methods of materials.
CO-3	Discuss the strengthening mechanisms of materials.
CO-4	Appreciate the failure mechanisms in materials.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-3	3	-	1	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-4	3	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Elastic and plastic behaviour of materials, Concept of stress and strain.

Dislocation Theory: Imperfections in Solids, Concept of dislocations, Edge, Screw and mixed dislocation, Burger Vector, Stress field around dislocation; Dislocation Movement, Dislocation Glide and climb, Force acting on dislocations, Core of the dislocation and the Peierls Stress, Nabarro stress, Energy of dislocations, Dissociation or Combination of Dislocations, Frank-Read Source: Dislocation Multiplication, Dislocation Pileups.

Strengthening Mechanisms: Grain boundary strengthening, Hall-Petch Relation, Hall-Petch strengthening limit, Strengthening from second phase, Solid Solutions strengthening, Precipitation Hardening, Interaction between particles and dislocations-Particle Cutting and Orowan mechanism, Fibre Strengthening, Martensitic strengthening.

Tension Test: Elastic and plastic deformation, Time Independent and time dependent Deformation, Tension Test Setup and specimens, Typical Stress strain diagram, necking criterion, Yield Point Phenomenon, Strain Aging, Holloman power curve, Factors affecting shape and magnitude of stress-strain curve.

Compression Test: Needs of compression test, Compression Test Setup and specimens, Behaviour of ductile and brittle materials in Compression, Barreling.

Impact Testing: The brittle failure problem and notch sensitivity, notched bar impact test; Significance and Specialized test for transition temperature; Metallurgical factors affecting transition temperature; Temper Embrittlement.

Introduction to Fracture: Elementary theories of fracture. Griffiths theory of brittle fracture, ductile fracture.

Introduction to Fatigue Testing: Significance of fatigue test, stress cycles, S-N curve, fatigue limit, mechanism of fatigue failure, effect of stress concentration, size, surface condition and environments on fatigue, effect of metallurgical variables on fatigue properties.

Introduction to Creep Testing: The creep curve, creep properties of metals. Stress-rupture test, deformation and fracture at elevated temperature, theories of creep, Prediction of long-time properties, Creep resistant materials, Effect of metallurgical variables on creep.

Learning Resources:

Text Books:

1. George E. Dieter, Mechanical Metallurgy, McGraw Hill, New York, (ISBN 0-07-016853-8) TA405.D53, 1986, 3rd Edition.
2. Norman E. Dowling, Mechanical Behavior of Materials, Prentice-Hall, Upper Saddle River, New Jersey, (ISBN0-13-905720-X) 1999, 2nd Edition.
3. Derek Hull and D.J. Bacon: Introduction to Dislocations, Pergamon Press, 2008.

Reference Books:

1. Thomas H. Courtney, Mechanical Behavior of Materials, McGraw Hill, New York, 2nd Edition, 2000. (ISBN0-07-028594-2) TA405.C859
2. William F. Hosford, Mechanical Behavior of Materials, Cambridge University Press 2005
3. MA Meyers and K Chawla, Mechanical Behavior of Materials, Prentice Hall
4. David Broek, Elementary Engineering Fracture Mechanics, Martinus Nijhoff Publishers, Hingham, Massachusetts, 3rd Edition, 1984. (ISBN 90-247-2656-5)
5. Richard W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, John Wiley & Sons, New York, 3rd Edition, 1989. (ISBN 0-471-63589-8) TA417.6H46
6. Donald Peckner (editor) The Strengthening of Metals, Reinhold Publishing,New York, 2nd Edition, 1967.

MM1381 **1-0-0 (0.5)**

Fractal Course I

Pre-Requisites: None

Course Outcomes:

CO-1	Acquire an in-depth understanding of the specific topic covered in the course, which could range from a particular technology, method, or recent advancement in Metallurgical and Materials Engineering.
CO-2	Develop hands-on skills relevant to the course topic, such as using specific tools, software, or techniques.
CO-3	Apply learned concepts to solve focused and practical engineering problems related to the course content
CO-4	Understand the interdisciplinary aspects and applications of the course to solve real-world industrial problems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	3	-	-	-	-	-	-	-	-	-	1	1	1	2
CO-2	-	-	-	2	2	3	3	-	-	-	-	-	-	1	-	-
CO-3	-	-	3	2	2	-	-	-	-	-	-	-	-	2	-	1
CO-4	-	-	-	-	-	-	-	-	1	3	-	2	-	-	1	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

This one-week course aims to bridge the gap between academic learning and industry application / latest research developments, providing students with a comprehensive understanding of the Metallurgical and Materials Engineering field and enhancing their readiness for professional careers.

a. Structure: Lectures delivered by an expert from the Metallurgical and Materials Engineering Industry / R&D Organization / Academic Institution (SPARK Collaborators / Foreign Subject Experts in GIAN program / Adjunct Professors from Foreign Universities @ NITW).

b. Content: Topics covering current practices, case studies, technological advancements, and future trends.

c. Interactive Sessions: Q&A sessions, discussions, and case study analyses to foster interaction between students and the subject expert.

d. Assessment: the mode of assessment (Participation, a short reflective report / a presentation summarizing key takeaways from the lectures / Objective or descriptive type exam, etc.) will be decided by the subject expert

Learning Resources:

1. Course material and any learning resources suggested by the experts

MM1307 **0-1-2 (2)**

Powder Metallurgy Laboratory

Pre-Requisites: None

Course Outcomes:

CO-1	Synthesize metallic and ceramic powders
CO-2	Determine the characteristics of powders
CO-3	Determine the physical characteristics of green compact
CO-4	Evaluate the physical and mechanical properties of sintered compacts

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	2	2	–	1	2	2	–	–	–	–	–	–
CO-2	2	–	–	–	3	2	–	1	2	2	–	–	–	–	2	–
CO-3	2	–	–	–	3	2	–	1	2	2	–	–	–	–	–	2
CO-4	2	–	–	–	–	2	–	1	2	2	–	–	–	–	3	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Compaction and Sintering of different powders, Wet Chemical Analysis, Self-Propagating High Temperature Synthesis (SHS) of Powder, Ball Milling, Characterization of different Synthesized Powders, Structure-Property correlation study of Sintered Samples.

Demonstration of additive manufacturing equipment and the products available in the Institute

Learning Resources:

Text Books:

1. R. M. German, Powder Metallurgy & Particulate Materials Processing, MPIF, 2005, 3rd Edition.
2. Alloy Phase Diagrams, ASM Handbook, Volume 3.

MM1309 **0-0-2 (2)**

Mechanical Metallurgy Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Operate mechanical testing equipment for measuring materials properties
CO-2	Analyse the data from mechanical testing
CO-3	Suggest suitable equipment for determination of mechanical properties of bulk and sheet metal products

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO-1	3	-	-	-	3	-	-	-	2	-	-	-	-	1	-	3
CO-2	3	2	-	-	3	-	-	-	2	-	-	-	-	1	-	3
CO-3	3	-	-	-	3	-	-	-	-	-	-	-	-	1	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Determination of Vickers, Brinell and Rockwell hardness; Dynamic Hardness Test: Poldi and Rebound; Ductile to Brittle Transition Temperature Test; Erichsen Ductility test, Standard impact tests: Charpy and IzodTest; Tensile/ Compression Test.

Learning Resources:

Text Books:

1. Mechanical Behavior of Materials Laboratory Manual
2. Hardness Testing Principles and Applications-ASM International (2011), Konrad Herrman
3. ASM Handbook, Volume 20, Materials Selection and Design. Materials Park, OH: ASM International, 1990.
4. ASM Handbook, Volume 8, Mechanical Testing and Evaluation. Materials Park, OH: ASM International, 1990.
5. ASTM E18-03: Standard Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials. West Conshohocken, PA : ASTM International, 2004.
6. Davis, Harmer Elmer, G. Hauck, and G. Troxell. The Testing of Engineering Materials. Boston: Mcgraw-Hill College, 1982.

6th Semester

MM1302 **3-0-0 (3)**

Computational Materials Engineering

Pre-Requisites: MM1203, MM1207, CS1101

Course Outcomes:

CO-1	Discuss the importance of modelling and simulation in materials engineering.
CO-2	Describe the foundations of CALPHAD approach and MD simulation.
CO-3	Solve one dimensional finite element problems.
CO-4	Calculate phase diagrams using CALPHAD software.
CO-5	Perform molecular dynamics and finite element simulations.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	1	–	–	3	–	–	–	1	2	–	1	2	3	–	–
CO-2	3	2	2	–	3	–	–	–	1	2	–	1	2	–	–	2
CO-3	3	1	1	–	3	–	–	–	1	2	–	1	2	3	–	–
CO-4	3	1	1	–	3	–	–	–	1	2	–	1	2	–	–	–
CO-5	3	2	2	–	3	–	–	–	1	2	–	1	2	–	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Physical modelling of material problems, models in metallurgy: Hall-Petch relation, Arrhenius relation, equations to predict Ms and β- transus temperature. Finite element method: introduction, solving 1-D structural and heat transfer problems. Computational thermodynamics: CALPHAD approach to calculate equilibrium diagrams, introduction to ThermoCalc and calculation of binary and pseudo binary phase diagrams. Molecular Dynamics (MD) simulations: Types of MD simulations, types of potentials used in MD simulations, using MD simulations to predict melting point of pure metals. Introduction to Monte Carlo (MC) methods in material engineering, application of MC to solve integrals. Basics of data science, linear regression models, data analytics in materials

Laboratory component: Plotting thermodynamic functions in unary, binary and ternary systems, Calculation of phase equilibria (unary system), Calculation of Fe-C phase equilibria, Calculation of phase equilibria of non-ferrous alloy system, Calculation of isopleth, Finite element modelling of simple compression test/ 1D steady state heat transfer, Simulation of 1-D heat transfer, Using LAMMPS to measure the melting temperature of pure metals.

Learning Resources:

Text Books:

1. Richard Lesar, Introduction to Computational Materials Science- Fundamentals to Applications, Cambridge University Press, Cambridge UK, 2013
2. June Gunn Lee, Computational Materials Science-An Introduction, CRC Press, 2015
3. Computational Materials Engineering Laboratory Manual

Reference Books:

1. Ellad B. Tadmor, Ronald E. Miller, Modeling Materials (Continuum, Atomistic and Multiscale Techniques), Cambridge University Press, New York, 2011 2.
2. Michael Heath, Scientific Computing: An introduction survey, McGraw Hill, 2002 R. B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena 2ed., Wiley- India, 2021

Other Suggested Readings:

1. NPTEL course on Foundations of Computational Materials Modelling, https://nptel.ac.in/courses/112106289
2. https://ocw.mit.edu/courses/3-021j-introduction-to-modeling-and-simulation-spring-2012/
3. http://www.opencalphad.com/
4. https://www.lammps.org/
5. https://nanohub.org/

MM1304 **3-1-0 (4)**

Non-Ferrous Extractive Metallurgy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify techniques for extraction and refining of nonferrous metals.
CO-2	Differentiate pyro- and hydro-metallurgical techniques.
CO-3	Design flow sheets for extraction and refining of metals.
CO-4	Assess energy efficiency in extraction of Non-Ferrous Metals.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	2	2	–	–
CO-2	3	–	–	–	–	–	–	–	–	–	–	–	2	2	–	–
CO-3	3	–	–	–	–	–	–	–	–	–	–	–	2	2	–	–
CO-4	3	–	–	–	–	–	–	–	–	–	–	–	2	2	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Thermodynamics of Extraction: Thermochemistry, Ellingham Diagrams, Predominance Area Diagrams, Free Energy Calculations.

Extraction Principles: Extractive Metallurgy of Sulphide Ores- Copper, Zinc, Lead, Nickel. Extractive Metallurgy of Oxide Ores- Aluminum, Magnesium, Titanium, Zirconium and Uranium. Extraction of Lithium and Rare-earth metals

Learning Resources:

Text Books:

1. H. S. Ray, R. Sridhar and K.P. Abraham, Extraction of Non-Ferrous Metals, Affiliated East –West, 1985.
2. R. Raghavan, Extractive Metallurgy of Non-Ferrous Metals, Vijay Nicole Imprints Private Limited, 2016.
3. H.S. Ray and A. Ghosh, Principles of extractive metallurgy, Wiley, 1991.

Reference Books:

1. Seshadri Seetharaman (Ed), Treatise on Process Metallurgy, Volume 3: Industrial Processes, Elsevier, 2014.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/105/113105021/ (Non-Ferrous Extractive Metallurgy – Prof H S Ray, IIT Kharagpur).

MM1306 **0-1-4 (3)**

Product Development

Pre-Requisites: MM1101

Course Outcomes:

CO-1	Express product/ process design ideas using 2D or 3D sketches or flow charts.
CO-2	Model the components/ processes with specifications and appropriate materials.
CO-3	Develop a prototype of the product/ process.
CO-4	Evaluate the entire product/ process incorporating user's feedback.
CO-5	Explore the scope for protecting novelty of the product/ process through patent.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	-	-	2	3	3	3	2	2	3	3	2	3	2	1	2	2
CO-2	-	-	2	3	3	3	2	2	3	3	2	3	3	1	3	2
CO-3	-	-	2	3	3	3	2	2	3	3	2	3	2	1	3	3
CO-4	-	-	2	3	3	3	2	2	3	3	2	3	3	1	3	3
CO-5	-	-	2	3	3	3	2	2	3	3	2	3	1	1	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Design thinking process for product/ process development: Review of five step design thinking process of Empathize- Define- Ideate- Prototype- Test.

Project selection: Identification of the problem through empathy, formulate and ideate to solve the problem.

Product/ process development:
Sketching: 2D and 3D sketching: Students will sketch the concept on drawing sheets/ digital screens. The drawings will contain the specifications of the geometric form.

3D Modelling: Develop the 3D model features including free form surfaces, final product design specifications, Parametric design.

Physical component development: Development of components: fabrication of actual components of the product using the materials and tools available in the lab, Iterations.

Iterative improvement of the product and report writing: Development of assemblies/mock-up models/ working models/ prototypes/functional models/products, Testing and design review, Report writing.

IPR: Different forms of innovations emanating from the human mind and their protection using different tools of IPR, Basic introduction to Patents, Trademarks, Copyright, Industrial Designs Registrations, Geographical Indications Trade Secrets. Filing of IPR, implications, Ethics and societal implications of Intellectual Property Rights.

Learning Resources:

Textbooks:

1. Sullivan, Brian, The design studio method: creative problem solving with UX sketching, Focal Press, 2016.
2. Gaurav Verma, Matt Weber, Autodesk Fusion 360 Black Book 6Ed., Cadcamcae Works, 2023.
3. Class Junghans, Adam Levy, Intellectual Property Management: A guide for Scientists, Engineers, Financers and Managers, Wiley, 2006.

Other learning resources:

1. Self-Paced Tutorials https://help.autodesk.com/view/fusion360/ENU/courses/
2. Autodesk product documentation: https://help.autodesk.com/view/fusion360/ENU/?guid=GUID1C665B4D-7BF7-4FDF-98B0-AA7EE12B5AC2

MM1382 **1-0-0 (0.5)**

Fractal Course II

Pre-Requisites: None

Course Outcomes:

CO-1	Acquire an in-depth understanding of the specific topic covered in the course, which could range from a particular technology, method, or recent advancement in Metallurgical and Materials Engineering.
CO-2	Develop hands-on skills relevant to the course topic, such as using specific tools, software, or techniques.
CO-3	Apply learned concepts to solve focused and practical engineering problems related to the course content
CO-4	Understand the interdisciplinary aspects and applications of the course to solve real-world industrial problems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	3	-	-	-	-	-	-	-	-	-	1	1	1	2
CO-2	-	-	-	2	2	3	3	-	-	-	-	-	-	1	-	-
CO-3	-	-	3	2	2	-	-	-	-	-	-	-	-	2	-	1
CO-4	-	-	-	-	-	-	-	-	1	3	-	2	-	-	1	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

This one-week course aims to bridge the gap between academic learning and industry application / latest research developments, providing students with a comprehensive understanding of the Metallurgical and Materials Engineering field and enhancing their readiness for professional careers.

a. Structure: Lectures delivered by an expert from the Metallurgical and Materials Engineering Industry / R&D Organization / Academic Institution (SPARK Collaborators / Foreign Subject Experts in GIAN program / Adjunct Professors from Foreign Universities @ NITW).

b. Content: Topics covering current practices, case studies, technological advancements, and future trends.

c. Interactive Sessions: Q&A sessions, discussions, and case study analyses to foster interaction between students and the subject expert.

d. Assessment: the mode of assessment (Participation, a short reflective report / a presentation summarizing key takeaways from the lectures / Objective or descriptive type exam, etc.) will be decided by the subject expert

Learning Resources:

1. Course material and any learning resources suggested by the experts

MM1308 **0-1-2 (2)**

Computational Materials Engineering Laboratory

Pre-Requisites: MM1203, MM1207, CS1101

Course Outcomes:

At the end of the course, the student will be able to

CO-1	Discuss the importance of modelling and simulation in materials engineering.
CO-2	Describe the foundations of CALPHAD approach and MD simulation.
CO-3	Solve one dimensional finite element problems.
CO-4	Calculate phase diagrams using CALPHAD software.
CO-5	Perform molecular dynamics and finite element simulations.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	1	–	–	3	–	–	–	1	2	–	1	2	3	–	–
CO-2	3	2	2	–	3	–	–	–	1	2	–	1	2	–	–	2
CO-3	3	1	1	–	3	–	–	–	1	2	–	1	2	3	–	–
CO-4	3	1	1	–	3	–	–	–	1	2	–	1	2	–	–	–
CO-5	3	2	2	–	3	–	–	–	1	2	–	1	2	–	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Laboratory component: Plotting thermodynamic functions in unary, binary and ternary systems, Calculation of phase equilibria (unary system), Calculation of Fe-C phase equilibria, Calculation of phase equilibria of non-ferrous alloy system, Calculation of isopleth, Finite element modelling of simple compression test/ 1D steady state heat transfer, Simulation of 1-D heat transfer, Using LAMMPS to measure the melting temperature of pure metals.

Learning Resources:

Text Books:

1. Richard Lesar, Introduction to Computational Materials Science- Fundamentals to Applications, Cambridge University Press, Cambridge UK, 2013
2. June Gunn Lee, Computational Materials Science-An Introduction, CRC Press, 2015
3. Computational Materials Engineering Laboratory Manual

Reference Books:

1. Ellad B. Tadmor, Ronald E. Miller, Modeling Materials (Continuum, Atomistic and Multiscale Techniques), Cambridge University Press, New York, 2011 2.
2. Michael Heath, Scientific Computing: An introduction survey, McGraw Hill, 2002 R. B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena 2ed., Wiley- India, 2021

Other Suggested Readings:

1. NPTEL course on Foundations of Computational Materials Modelling, https://nptel.ac.in/courses/112106289
2. https://ocw.mit.edu/courses/3-021j-introduction-to-modeling-and-simulation-spring-2012/
3. http://www.opencalphad.com/
4. https://www.lammps.org/
5. https://nanohub.org/

MM1310 **0-1-2 (2)**

Materials Characterization Laboratory

Pre-Requisites: **None.**

Course Outcomes:

CO-1	Quantify microstructural features using image analysis tool.
CO-2	Observe the fracture surface and identify the mode of fracture.
CO-3	Analyze the chemical composition of materials through SEM-EDS.
CO-4	Determine phases and crystal structure of the material using XRD technique.
CO-5	Determine the thermal properties of materials.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	3	-	-	-	1	2	-	-	-	1	-	3
CO-2	3	-	-	-	3	-	-	-	1	2	-	-	-	1	-	3
CO-3	3	3	-	-	3	-	-	-	1	2	-	-	-	1	-	3
CO-4	3	-	3	-	3	-	-	-	1	2	-	-	-	1	-	3
CO-5	3	-	3	-	3	-	-	-	1	2	-	-	-	1	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Image analysis of microstructures using OM, Microstructural analysis using SEM, Fractography analysis using SEM, Chemical analysis of phases using SEM-EDS, Determination of crystal structures, indexing and identification of phases using X-Ray Diffractometer, Determination of lattice strain and crystallite size using X-Ray Diffractometer, Oxidation kinetics using TGA / DTA, Determination of thermal properties using DSC.

Learning Resources:

Text Books:

1. Materials Characterization Techniques, S Zhang, L. Li and Ashok Kumar, CRC Press, 2008.
2. An Introduction to Material Characterization, Khangaonkar P R, Penram Intl. Publishing (India) Pvt. Ltd, Mumbai,2010.
3. Scanning electron microscope (SEM) instrumentation: Scanning Electron Microscopy and X-Ray Microanalysis. Springer, Goldstein JI, Newbury DE, Michael JR, Ritchie NW, Scott JH, Joy DCNew York, NY, 2018, 4th Edition.
4. Elements of X-Ray Diffraction, B.D.Cullity and S.R.Stock, 3rd Edition, Prentice Hall, NJ, 2001.

Reference Books:

1. Materials Characterization Techniques Laboratory Manual.

Other Suggested Readings:

1. https://youtu.be/KfQ4VNpWN4M
2. https://www.youtube.com/watch?v=vVm0ZW9zBtQ
3. https://www.youtube.com/watch?v=UuHofNW40Yw

4. https://www.youtube.com/watch?v=Mr9-1Sz_CK0
5. https://www.youtube.com/watch?v=ArPXfPjOJQc
6. https://www.youtube.com/watch?v=07iZ7-IEyYE
7. https://www.youtube.com/watch?v=yguvwX_ia_A&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=2

7th Semester

MM1401 **3-0-0 (3)**

Metal Joining

Pre-Requisites: **None**

Course Outcomes:

CO-1	Differentiate welding processes
CO-2	Describe the arc characteristics
CO-3	Identify various welding defects and remedial measures
CO-4	Discuss the principles of post-weld heat treatment

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	3	3	–	–	–
CO-2	3	–	–	–	–	–	–	–	–	–	–	–	–	3	–	–
CO-3	3	2	3	1	–	–	–	–	–	–	–	–	–	3	–	–
CO-4	3	2	2	–	–	–	–	–	–	–	–	3	–	3	–	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Metal joining: Fundamentals of welding, brazing, and soldering, classification of welding processes, types of weld joints, welding positions, welding arc characteristics, arc initiation, arc stability, metal transfer, fusion welding: Oxyfuel Gas Welding, Carbon Arc Welding, Gas Tungsten Arc Welding, Plasma Arc Welding, Shielded Metal Arc Welding, Gas Metal Arc Welding, Flux-Cored Arc Welding, Submerged Arc Welding, electro-slag and electro-gas welding, solid-state welding: forge welding, ultrasonic welding, diffusion welding, explosive welding, friction welding and friction stir welding, high energy beam welding-electron beam welding, laser beam welding, other welding processes: resistance welding, spot, seam welding, thermit welding, solidification, weld microstructure, post weld heat treatment of welds

Welding defects: solidification cracking, incomplete fusion, insufficient penetration, weld undercut, weld cracks, weld porosity, slag inclusions, tungsten inclusion, reinforcement, overlap, burn through, crater cracks, spatter, arc strike.

Introduction to additive manufacturing (AM): Basic principles, additive Vs Subtractive manufacturing, advantages and challenges in AM, classification of AM systems, generic AM process: CAD, Conversion of STL, Transfer to AM machine and STL file manipulation, machine setup, Build, Removal, Distinction between AM and CNC machining, Reverse engineering.

Learning Resources:

Textbooks:

1. Cary, Howard B. and Scott C. Helzer, Modern Welding Technology. Upper Saddle River, New Jersey: Pearson Education, USA, 2005.
2. Sindo Kou, Welding metallurgy, John Willey, 2003, 2nd edition, USA.
3. J.F. Lancaster, Metallurgy of Welding, Abington Publishing, 6th edition, England. 1999.
4. Richard Little, Welding and Welding Technology, McGraw Hill, 1st edition, 2001.
5. Metals Handbook-Welding, Brazing and Soldering, American Society for Metals, 10th edition, Volume 6, USA, 1993.

6. Inspection and testing of weld joints Welding handbook, American Welding Society, 7th edition, USA, 1983.

Reference Books:

1. Metals Handbook-mechanical testing and evaluation, American Society for Metals, Volume 8, USA, 1993.
2. Welding handbook, American Welding Society, 8th edition, vol.1 & 2, USA, 1987.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/106/11310608
2. https://www.twi-global.com/technical-knowledge/faqs/what-is-welding

MM1403 **0-0-2 (1)**

Metal Joining Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	To demonstrate the arc welding practices (Lap and butt joint)
CO-2	To acquire knowledge on welding tools and welding equipment (GTAW, GMAW and SMAW)
CO-3	To understand the joining of various metals
CO-4	To evaluate the microstructure and hardness profile of weldments.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	3	1	-	-	2	3	-	-	3	-	-	-
CO-2	3	-	-	-	3	1	-	-	2	3	-	-	3	-	-	-
CO-3	3	-	-	-	3	1	-	-	2	3	-	-	3	-	-	-
CO-4	3	-	-	2	3	1	-	-	2	3	-	-	3	-	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

1. Demonstration of the gas tungsten arc welding (GTAW) of a given sample
2. Demonstration of the gas metal arc welding (GMA) of a given sample
3. Demonstration of the shielded metal arc welding (SMAW) welding of a given sample
4. Study the microstructural changes in various zones of welded samples.
5. Correlation of the microstructure and hardness profile of the given weldment
6. Identification of metal defects using liquid penetrant and magnetic particle testing

Learning Resources:

Text Books:

1. Robert W Messler, Jr. “Principles of welding, Processes, physics, chemistry and metallurgy”, Wiley, 2004.
2. Parmer R. S., ‘Welding processes”, Khanna Publishers, 1997
3. Sidney H Avner, Introduction to Physical Metallurgy, 2nd Edition, McGraw-Hill, 1997.
4. Kalpakjian and Schmid, Manufacturing Engineering and Technology, Prentice Hall, New Jersey, 2013.
5. Metal joining laboratory manual

Reference Books:

1. R. Balasubramaniam (Adapted): Calister’s Materials Science and Engineering, 7th Edition, Wiley India (P) Ltd, 2007.
2. Sindo Kou, Welding metallurgy, John Willey, 2003, 2nd Edition, USA.
3. Metals Handbook-mechanical testing and evaluation, ASM, Volume 8, USA, 1993.

Other Suggested Readings:

1. https://www.youtube.com/watch?v=gCCdiksvXMU
2. https://www.youtube.com/watch?v=QmhI-ZL40dw
3. https://www.youtube.com/watch?v=tlE3eK0g6vU

MM1405 **0-0-2 (1)**

Metal Processing Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Evaluate microstructure and hardness profile of weldments.
CO-2	Inspect metal defects using NDT techniques.
CO-3	Demonstrate the effect of cold working and annealing on microstructure.
CO-4	Practice rolling of copper, brass, plain carbon steel and stainless steel.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	3	1	-	-	2	3	-	-	3	-	-	3
CO-2	3	-	-	-	3	1	-	-	2	3	-	-	3	-	-	3
CO-3	3	-	-	-	3	1	-	-	2	3	-	-	3	-	-	-
CO-4	3	-	-	-	3	1`	-	-	2	3	-	-	3	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Perform rolling of copper, brass, stainless steel and plain carbon steel using laboratory rolling mill, Study of mechanical properties and microstructural change of cold worked metals, Perform annealing of cold worked metal and observe microstructural changes, Effect of strain rate studies on mechanical properties.

Learning Resources:

Text Books:

1. Baldevraj, Practical Non-destructive Testing, Wood head publishing limited, 2002
2. George E. Dieter, Mechanical Metallurgy, 3rd Edition, McGraw Hill, New York, 2013.
3. Sidney H Avner, Introduction to Physical Metallurgy, 2nd Edition, McGraw-Hill, 1997.
4. Kalpakjian and Schmid, Manufacturing Engineering and Technology, Prentice Hall, New Jersey, 2013.
5. Metal processing laboratory manual

Reference Books:

1. R. Balasubramaniam (Adapted): Calister's Materials Science and Engineering, 7th Edition, Wiley India (P) Ltd, 2007.
2. Sindo Kou, Welding metallurgy, John Willey, 2003, 2nd Edition, USA.
3. Metals Handbook-mechanical testing and evaluation, ASM, Volume 8, USA, 1993.

Other Suggested Readings:

1. https://www.youtube.com/watch?v=gCCdiksvXMU
2. https://www.youtube.com/watch?v=bWtbJWViDCo
3. https://www.youtube.com/watch?v=tlE3eK0g6vU

MM1489 **0-0-0 (2)**

Seminar & Technical Writing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a topic in metallurgical and materials engineering research.
CO-2	Conduct thorough literature survey.
CO-3	Prepare a comprehensive report.
CO-4	Discuss the topic with peers using multimedia tools.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	–	–	2	2	–	–	1	–	–	2	1	2	2	2
CO-2	3	3	3	2	2	2	–	–	1	–	–	2	1	2	2	2
CO-3	–	–	–	–	–	–	–	3	1	3	–	2	–	–	–	–
CO-4	–	–	–	–	–	–	–	3	1	3	–	2	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- Read relevant patents/publications and include the necessary information in the report

The student is expected to consolidate the ideas from these lectures/patent/publications searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Clarity on the topic	10%
II	List of lectures attended and literature surveyed	40%
III	Report	20%
IV	Presentation	20%
V	Response to questions	10%

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II	X			
III		X		
IV			X	X
V			X	

MM1491 **0-0-0 (2)**

Short Term Industrial/Research Experience

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	3	3	3	–	–	–	–	–	–	3	–	–	–	–
CO-2	2	2	2	2	2	–	–	3	3		3	3	–	–	–	–
CO-3	–	–	–	–	–	3	3	–	–	–	–	3	–	–	–	–
CO-4	–	–	–	–	–	–	–	–	–	3	–	3	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Every student has to undergo either a Summer Internship / EPICS / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The EPICS/research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Relevance of the area of work	10%
II	Performance of the Task	20%
III	Crucial learnings from the work	40%
IV	Report Preparation	10%
V	Presentation and Response to questions	20%

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

MM1495 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the research problem based on literature survey.
CO-2	Propose the plan of research work.
CO-3	Conduct experimental/simulation work.
CO-4	Analyze the experimental/simulation data.
CO-5	Prepare a comprehensive report.
CO-6	Deliver an oral presentation using ICT tools.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	-	3	-	-	-	-	2	-	2	3	1	2	2	-
CO-2	3	3	3	3	-	-	2	-	2	-	2	3	1	2	2	-
CO-3	3	-	3	3	3	2	-	-	2	-	2	-	2	2	2	1
CO-4	3	3	3	3	3	-	-	-	2	-	2	3	2	2	2	2
CO-5	-	-	-	-	-	-	-	3	2	3	2	-	-	-	-	-
CO-6	-	-	-	-	-	-	-	3	2	3	2	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Identification of Problem Domain	10%
II	Study of existing literature and establishing clear objectives	20%
III	Planning of project and completing work with fair distribution within the team	40%
IV	Proper Documentation and Technical Writing	20%
V	Presentation and Response to questions	10%

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4	CO5	CO6
I	X					
II	X					
III		X	X			
IV				X	X	
V				X		X

8th Semester

MM1498 **0-0-0 (6)**

Major Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the research problem based on literature survey.
CO-2	Propose the plan of research work.
CO-3	Conduct experimental/simulation work.
CO-4	Analyze the experimental/simulation data.
CO-5	Prepare a comprehensive report.
CO-6	Deliver an oral presentation using ICT tools.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	-	3	-	-	-	-	2	-	2	3	1	2	2	-
CO-2	3	3	3	3	-	-	2	-	2	-	2	3	1	2	2	-
CO-3	3	-	3	3	3	2	-	-	2	-	2	-	2	2	2	1
CO-4	3	3	3	3	3	-	-	-	2	-	2	3	2	2	2	2
CO-5	-	-	-	-	-	-	-	3	2	3	2	-	-	-	-	-
CO-6	-	-	-	-	-	-	-	3	2	3	2	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

The B.Tech. Project work will be evaluated for 100 marks, with the following weightages:

Component	**Weightage**
Periodic evaluation by Guide	40 marks
Mid-term review	20 marks
End Semester viva-voce examination	40 marks
Total	100 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	**10%**
II	Literature Survey	**10%**
III	Objectives and Solution Methodology	**20%**
IV	Performance of the Task and clarity on the work	**40%**
V	Report Preparation	**10%**
VI	Presentation and Response to questions	**10%**

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4	CO5	CO6
I	X					
II		X				
III		X				
IV			X			
V				X	X	
VI				X		X

Refer to B.Tech. – Regulations for any further information regarding Mid-term review, End Sem evaluation, Template for report preparation and plagiarism

Professional Electives

MM1321 **3-0-0 (3)**

Fuels and Refractories

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the production of solid, liquid, and gaseous fuels.
CO-2	Classify the fuels and refractories specific to their operating conditions.
CO-3	Choose the optimum combination of fuels and refractories to minimize the overall cost
CO-4	Illustrate the composition, properties, testing, and applications of fuels and refractories.
CO-5	Evaluate the calorific value of fuels.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO-3	3	-	3	-	-	-	-	-	-	-	3	-	2	-	-	-
CO-4	2	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2
CO-5	2	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Solid, Liquid and Gaseous fuels: Origin of coals – types – properties – storage and pulverization of coal. Coke making by Beehive and byproduct coke ovens. Principles of Crude petroleum refining, cracking. Manufacture, properties and uses of producer gas, water gas, coke oven gas and Blast furnace gas.

Characterization of Fuels: Analysis. Calorific value of fuels – calculations. Efficiency of fuels.

Refractories: Classification of refractories, production, composition, properties, testing and application of common refractories such as Silica, Fire clay, Magnesite, Chrome and Dolomite refractories..

Selection of refractories: Selection of refractories for metallurgical applications such as coke ovens, blast furnace, LD and Copper convertors, soaking pits, Reheating furnaces and Heat Treatment furnaces.

Learning Resources:

Text Books:

1. J. D. Gilchrist, Fuels, Furnaces and Refractories, Pergamon, 2001.
2. 2. O. P. Gupta, Elements of Fuels, Furnaces and Refractories, Khanna Publishers, 1998.

Reference Books:

1. M. Peter, and B. Jenkin, Industrial and process furnaces: principles, design and operation. Butterworth-Heinemann, 2022.
2. W. Trinks and M. H. Mawhinney, Industrial Furnaces, John Wiley and Sons, 6th Edition, 2003.

Other Suggested Readings:

1. https://www.digimat.in/nptel/courses/video/113104008/L01.html

MM1323 **3-0-0 (3)**

Advanced Metallurgical Thermodynamics

Pre-Requisites: MM1203

Course Outcomes:

CO-1	Apply thermodynamic concepts in studying the phase diagrams
CO-2	Identify the importance of thermodynamics in solid state solutions
CO-3	Assess the role of thermodynamics in phase transformations
CO-4	Explain thermodynamics for heterogeneous systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	1	–	–	–	–	–	–	–	–	--	3	--	–
CO-2	3	–	–	1	–	–	–	–	–	–	–	–	–	3	–	--
CO-3	3	–	–	1	–	–	–	–	–	–	–	–	--	3	--	–
CO-4	3	--	--	1	–	–	–	–	–	–	–	–	--	3	–	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Basics: First, second and third laws of thermodynamics, thermodynamic potentials, Maxwell's relations, Clausius-Clapeyron equation. Solutions: solution models, regular, sub-regular, cluster variation models, multi-parameter models, quasi-chemical theory, statistical thermodynamics, multicomponent systems. **Equilibrium Concepts**: Unary, binary and multicomponent systems, phase equilibria, evolution of phase diagrams, metastable phase diagrams, calculation of phase diagrams, thermodynamics of defects. **Thermodynamics of Phase Transformations**: Melting and solidification, precipitation, eutectoid, massive, spinodal, martensitic, order disorder transformations and glass transition. First and second order transitions. Eutectic solidification, Eutectoid reaction, Bainitic transformation, Kinetics of eutectoid transformations, Martensitic Transformation. Heterogeneous Systems: Equilibrium constant, Ellingham diagrams and their application to commercially important reactions.

Learning Resources:

Text Books:

1. Physical Chemistry of Metals, Lawrence S. Darken & Robert W. Gurry, CBS Publishers & Distributors-Delhi, 1953.
2. Thermodynamics of Solids, Richard A. Swalin, John Wiley & Sons, Inc., 4th edition 1967
3. Phase Transformations in Metals and Alloys, David A. Porter, Kenneth E. Easterling and Mohamed Y. Sherif, CRC Press, Taylor & Francis Group, 3rd Edition, 2009.

Reference Books:

1. Introduction to the Thermodynamics of Materials, David R. Gaskell and David E. Laughlin, CRC Press, Taylor and Francis Group, 2017, 6th Edition.
2. Textbook of Materials and Metallurgical Thermodynamics, Ahindra Ghosh, Prentice Hall of India Pvt. Ltd., 2003.

3. Transformations in Metals, Paul G. Shewmon, Indo American Books.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/106/113106031/
2. web.mit.edu/16.unified/www/FALL/thermodynamics
3. materials.iisc.ernet.in/~abinand/courses/thermos

MM1325 **3-0-0 (3)**

Ferroalloy Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the use of ferroalloys in the production of steel
CO-2	Discuss various reaction mechanisms during the production of ferroalloys
CO-3	Discuss the technology of production of ferroalloys
CO-4	Assess the environmental concern during production of ferroalloys

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-2	1	-	-	2	-	-	-	-	-	-	-	-	3	1	-	-
CO-3	1	-	1	-	-	-	-	-	-	-	-	-	3	-	1	-
CO-4	1	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Ferroalloys: History and development of ferroalloys, classification of ferroalloys, classification of ferroalloy processes, and overview of Indian ferroalloy sector.

Theory of ferroalloys production: Concepts, thermodynamic and kinetic principles

Ferroalloy Processing: techniques, electrical and thermal processes, existing production process of important ferroalloys e.g., Fe-Cr, Fe-Mn, Fe-Si, Fe-V, Fe-Ti, Fe-W, Fe-Nb, Fe-Mo, Fe-Ni, Fe-Zr, Fe- B etc., recent advances in ferroalloy technology

Energy and emission issues of the ferroalloys industry: Energy demand for ferroalloys making, CO2 emission from ferroalloys production, recent developments in emission control**.**

Learning Resources:

Text Books:

1. Ferroalloys: Theory and Practice, Mikhail Gasik, Viktor Dashevskii, Aitber Bizhanov, Springer, 2020, First edition.
2. Handbook of Ferroalloys: Theory and Technology, Michael Gasik, Elsevier, 2013, First edition.

Reference Books:

1. Production of Manganese ferroalloys, Sverre E. Olsen, Sverre Olsen, Merete Tangstad, Tor Lindstad, Tapir Akademisk Forlag, 2007, First edition.

Other Suggested Readings:

1. The complete book on Ferroalloys, B.P. Bhardwaj, NIIR Project Consultancy Services, 2008, First edition.

MM1327 **3-0-0 (3)**

Nuclear Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the concepts of nuclear reactor engineering
CO-2	Classify reactor components and their materials
CO-3	Describe the properties required for structural components of nuclear reactors
CO-4	Identify techniques for disposal of radioactive wastes
CO-5	Explain processing of nuclear grade materials

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	1	–	–	–	–	–	–	–	–	–	3	–	–	–
CO-2	3	–	1	–	–	–	–	–	–	–	–	–	3	1	–	–
CO-3	3	–	2	–	–	2	–	–	–	–	–	–	3	–	–	–
CO-4	3	–	3	–	–	–	2	–	–	–	–	–	3	–	–	–
CO-5	3	–	1	–	–	–	–	–	–	–	–	–	3	3	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Elements of Nuclear Engineering: Elementary concepts of nuclear reactors. Structure of the nucleus, binding energy, fission reactions, fusion reactions, neutron cross sections, moderation of neutrons

Nuclear Reactor Components: Reactors and Materials. Classification of nuclear reactors. Materials for nuclear fission reactors viz., fuels, moderators, control rods, and structural materials. Fabrication of fuel and cladding materials. Fusion reactor components and structural material requirements. Advanced Fusion Steels – Alloy Design and Thermo-Mechanical treatment**.**

Radiation: Radiation Effects. Interaction of radiation with materials. Radiation hazards, safety and shielding. Uses of radioactive isotopes. Nuclear Reactor Waste Disposal: Disposal of radioactive wastes.

Processing of Nuclear reactor Materials: Production of Nuclear Grade Materials, general methods of nuclear minerals processing. Production metallurgy of nuclear grade uranium, thorium, beryllium and zirconium. Production of enriched uranium. Processing of spent fuel and extraction of plutonium.

Indian Nuclear Power Programme: Indian Reactors and Nuclear Energy Programme in India.

Learning Resources:

Text Books:

1. John R. Lamarsh and Anthony J. Baratta, Introduction to Nuclear Engineering, Prentice Hall, 2001.
2. S. Glasstone and A. Sesonke, Nuclear Reactor Engineering, Van Nostrand, 1994.
3. J. Kenneth Shultis and Richard E. Faw, Fundamentals of Nuclear Science and Engineering, Marcel Dekkar, 2002.
4. Konings, Rudy, and Roger E. Stoller. Comprehensive nuclear materials. Elsevier, 2020.

Reference Books:

1. H. S. Ray, R. Sridhar and K. P. Abraham, Extraction of Non-Ferrous Metals, Affiliated East-West Press, 1985
2. Geoffrey F. Hewitt and John G. Collier, Introduction to Nuclear Power, Taylor and Francis, 1997.
3. K. Almenas and R .Lee, Nuclear Engineering: An Introduction, Springer Verlag, 1992.

Other Suggested Readings:

1. NPTEL Courses
2. TatjanaJevremovic, Nuclear Principles in Engineering, Springer, 2009.
3. Kenneth D. Kok, Nuclear Engineering Hand Book, CRC Press, 2009.

MM1329 **3-0-0 (3)**

Mineral Processing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify the mineral processing methods in extractive metallurgy
CO-2	Choose the right equipment for effective and economical mineral processing at a large scale
CO-3	Develop a suitable mineral processing flowsheet for a given ore
CO-4	Apply the mineral processing principles for concentrating lean ores

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-2	3	-	-	-	-	-	-	-	-	-	1	-	2	1	-	-
CO-3	3	-	-	-	-	-	-	-	-	-	1	-	3	2	1	-
CO-4	3	-	-	-	-	-	1	-	-	-	-	-	2	2	1	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Sampling, Comminution and Liberation: Mineral sources in India and abroad, physical and chemical characteristics of industrial minerals, economics of ore mineral processing, Sampling – fundamentals, representative sampling, comminution laws, Crushers-Jaw, Gyratory, Cone, Rolls, and toothed Rolls, Grinding- Batch and continuous grinding, Dry versus wet grinding, open circuit versus closed circuit grinding, grinding mills, ball mills, rod mills, tube mills, fine particle production, Liberation.

Sizing and classification: Laboratory sizing techniques and reporting of sizing data – sizing units, laboratory and industrial screening, types of screening, screening surfaces, screen efficiency, classification-types of classifiers - mechanical and hydraulic, sizing and sorting classifiers, Rake classifier, spiral classifier and cyclones, study of settling cones.

Gravity separation: Float & sink, heavy media separation, Jigging, flowing film separation, tabling

Froth floatation: contact angle, floatation reagents, floatation machines, floatation operation, column floatation, floatation practice for sulphide ores

Magnetic and electrical separation: Sorting of various minerals based on their magnetic properties, electro-magnetism, magnetic separators, methods of electrical charging of minerals, electrostatic separator, and high tension separator.

Learning Resources:

Text Books:

1. Wills' Mineral Processing Technology, B.A. Wills and J. Finch, Elsevier, 2016, 8th Edition
2. Textbook of Mineral Processing, D.V. Subba Rao, Scientific Publishers, 2017.

Reference Books:

1. Principles of Mineral Processing, M.C. Fuerstenau, and K.N. Han, SME Colorado, 2003.
2. Mineral Processing Technology, S.K. Jain, CBS Publisher, 2001, 2nd Edition.

Other Suggested Readings:

1. NPTEL Courses: https://nptel.ac.in/courses/105105171

MM1322 **3-0-0 (3)**

Machine Learning for Materials Engineering

Pre-Requisites: **CS1101**

Course Outcomes:

CO-1	Explain supervised and unsupervised machine learning algorithms
CO-2	Analyse materials dataset with descriptive and predictive methods
CO-3	Compare ML model performance for materials engineering problems
CO-4	Propose new compositions using ML models

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	1	1	–	–	1	–	–	–
CO-2	3	1	1	1	–	–	–	–	1	1	–	–	1	1	1	–
CO-3	3	1	1	1	–	–	–	–	1	1	–	–	1	1	1	–
CO-4	3	2	3	–	2	–	–	–	2	–	–	–	3	2	3	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Machine learning – Introduction, Supervised and unsupervised learning

Supervised learning – Regression, Linear and multi-variate regression cost functions, Logistic cost function, Regularization, Neural networks, SVM - Support Vector Machine, Training and cross validation sets, Data pre-processing and feature engineering, Systems design, Tree-based methods – Decision trees, Bagging, boosting, and stacked ensemble methods.

Unsupervised learning - Clustering – k-means algorithm and optimization functions.

ML applications in materials science and engineering: Mechanical property prediction of steels, Ti alloys, Al-Alloys and/or high entropy alloys (HEAs), Phase prediction of HEAs, Crystal structure predictions, Tribological property prediction of ceramic materials, ML models for materials discovery and design.

Learning Resources:

Text Books:

1. Kelleher, J. D., Mac Namee, B., & D'arcy, A, Fundamentals of Machine Learning for predictive data analytics: Algorithms, worked examples and case studies, MIT press, 2020.
2. Larose, D. T., Data Mining and predictive analytics, Wiley, 2015, 2nd Edition.
3. Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon Ong, Mathematics for Machine Learning, Cambridge University Press, 2020.
4. Turab Lookman, Francis J. Alexander Krishna Rajan, Editors, Information Science for Materials Discovery and Design, Springer Series in Materials Science, Volume 225, Springer, 2016.
5. Norbert Huber, Surya R. Kalidindi, Benjamin Klusemann, Christian Johannes Cyron, Editors, Machine Learning and Data Mining in Materials Science, Frontiers in Materials, 2020.

Reference Books:

1. Manaranjan Pradhan and Dinesh Kumar, Machine learning using Python, Wiley, 2019.
2. U Dinesh Kumar, Business Analytics, Wiley, 2017.

Other Suggested Readings:

1. https://towardsdatascience.com/ - A Medium publication sharing concepts, ideas, and codes.
2. https://machinelearningmastery.com/ by Jason Brownee
3. https://www.sciencedirect.com/science/article/abs/pii/S0927025621000859

MM1324 **3-0-0: 3**

Functional Materials

Pre-Requisites: **None**

Course Outcomes:

At the end of the course, the student will be able to

CO1	Classify functional materials
CO2	Explain structure-property correlation in functional materials
CO3	Discuss processing methods for functional materials
CO4	Select materials for advanced functional applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	1	1	–	–	1	–	–	–
CO-2	1	–	–	1	–	1	–	–	–	–	–	–	1	1	1	–
CO-3	3	1	1	1	–	1	–	–	1	1	–	–	2	1	1	–
CO-4	1	2	2	–	2	–	–	–	2	–	–	–	2	2	–	–

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

The Origin of Functional Materials (FMs), Potential Applications of FMs, Classification of FMs, Processing Techniques: Powder Metallurgy Route, Melt-processing Route, Vacuum arc melting, Vacuum induction melting, Vapor deposition and types

Specific properties of functional materials: Magnetic materials, Electronic Materials and Sensors, Electric Contact Materials, Conducting Thermoplastics and polymer composites, Surface coatings for functional applications, Biomaterials and Shape memory metals, Invar alloys

Batteries and fuel cell: Solar energy harvesting, Reflective and anti-reflective layers, Waste heat recovery materials

Microstructure-property correlations: characteristic dimensions and spatial variations, volume fraction, rule of mixtures and effective field parameters; characterization of FMs, macrostructural thermomechanical properties, material properties of ceramic-metal FMs, basic mathematical modelling.

Text Books:

1. Engineering Materials for Technological Needs, Vol. 2- Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications, D.D.L. Chung, World Scientific Publishing,2010.
2. Composite Materials- Functional Materials for Modern Technologies, D.D.L. Chung, Springer, 2002.
3. Functionally Graded Materials- Design, Processing and Applications, Y. Miyamoto, W.A. Kaysser, B.H. Rabin, A. Kawasaki, R.G. Ford (Eds), Springer,1999.

Reference Books:

1. Functionally Graded Materials - Nonlinear Analysis of Plates and Shells, Hui-Shen Shen, CRC Press,2009.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/105/113105081/
2. https://www.researchgate.net/publication/227194436_Functional_Materials_Properties_Processing_and_Applications
3. https://www.intechopen.com/books/7554

MM1326 **3-0-0 (3)**

Energy Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the need for energy production
CO-2	Discuss the principle and materials used in solar cell for energy production
CO-3	Describe the principle and materials used in fuel cell for energy production
CO-4	Describe the principle and materials need for lithium-ion battery technologies
CO-5	Understand the future battery concepts: beyond lithium ion technologies

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	2	–	–	–	1	1	2	-	-	-	-
CO-2	3	1	–	–	–	2	–	–	–	2	1	2	1	1	1	2
CO-3	3	1	–	–	–	2	–	–	–	2	1	2	1	1	1	2
CO-4	3	2	–	3	1	3	–	–	1	3	2	3	2	2	2	2
CO-5	3	2	–	2	1	3	–	–	1	3	2	3	2	2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Energy production and environment, World's energy consumption at various sectors, gap between energy production and energy needs, current Energy generation Technologies and their limitations, challenges in energy efficient material technology.

Basics of fuel cell: Fuel cell definition, fuel cell history, components of fuel cell, principle of fuel cell operation, thermodynamics and efficiency of fuel cell, electrochemical kinetics, types of fuel cells, their chemistries & advantages/disadvantages over the others, Recent developments and research on fuel cells.

Basics of battery: primary and secondary type batteries, types of batteries, lithium ion battery (LIB) & its components, working principle of LIB, thermodynamics and efficiency of LIB, types of materials used for LIBs, concepts of future batteries; beyond LIB technologies, Introduction to smart grid, materials for super capacitors.

Characterization techniques to study the Energy storage device characteristics.

Learning Resources:

Text Books:

1. Introduction to materials for advanced energy systems, Colin, Tong, Springer, 2019
2. Korthauer, R. ed., 2018. Lithium-ion batteries: basics and applications. Springer.
3. Liao, C., 2021. Fundamentals of rechargeable lithium ion and beyond lithium ion batteries. In Batteries: Materials principles and characterization methods (pp. 1-1). Bristol, UK: IOP Publishing.
4. Belharouak, I. ed., 2012. Lithium ion batteries: New developments. BoD–Books on Demand.

Reference Books:

1. Pérez-Lombard, L., Ortiz, J. and Pout, C., 2008. A review on buildings energy consumption information. Energy and buildings, 40(3), pp.394-398.
2. Kaja, N., 2015. An overview of energy sector in India. International Journal of Science and Research (IJSR), 6.
3. Sahu, S., 2008. Trends and patterns of energy consumption in India.
4. Bilgen, S.E.L.Ç.U.K., 2014. Structure and environmental impact of global energy consumption. Renewable and Sustainable Energy Reviews, 38, pp.890-902.

Other Suggested Readings:

1. https://www.doitpoms.ac.uk/tlplib/batteries/index.php

MM1328 **3-0-0 (3)**

Introduction to Nano Science and Technology

Pre-Requisites: **None**

Course Outcomes:

CO1	Identify the need for nano materials.
CO2	Explain the bottom-up and top-down approaches of nano material synthesis.
CO3	Describe the size effect on optical, electrical, mechanical, magnetic and thermal properties.
CO4	Review the applications of nano materials and nano devices

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	1	-	-	-	-	1	-	-	2	-
CO2	3	-	-	-	-	-	1	-	-	-	-	1	2	-	2	-
CO3	3	-	-	-	-	-	1	-	-	-	-	1	-	2	-	-
CO4	3	-	-	-	-	2	2	-	-	-	-	2	-	-	2	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Classification of Nanomaterials: Factors Influencing Properties of nanomaterials, Surface Area and Energy, effect of size on optical, electrical, physical & chemical properties.

Nanocarbon: Fullerene, Carbon Nanotubes (CNT), Purification & Sorting of CNTs, Growth Mechanism of CNT, 2D nanomaterials: Graphene, synthesis, properties and applications.

Synthesis of nanomaterials: Physical Methods: Mechanical Methods, Sputter Deposition, Chemical Vapour Deposition, Electric Arc Deposition, Ion Beam Technique, Molecular Beam Epitaxy. Chemical Methods: colloidal route, Sol-Gel Method, Hydrothermal synthesis, Sonochemical Synthesis, Microwave Synthesis.

Nanofluids, Natural Nanomaterials.

Learning Resources:

Text Books:

1. Textbook of Nanoscience and Nanotechnology, B. S. Murty et al., Universities Press (India) Private Limited, 2013.
2. Nanotechnology Principles and Practices, Sulabha K. Kulkarni, Capital Publishing Company, 2007.
3. Nanomaterials- From Research to Applications, H. Hosono, Y. Mishima, H. Takezoe, K.J.D Mackenzie, Elsevier, 2008.

Reference Books:

1. Introduction to Nanoscale Science and Technology, Massimilano Di Ventra, S. Evoy, James R. Heflin Jr, Springer, 2009.
2. Introduction to Nanotechnology, Charles P. Poole Jr., Frank J. Owens, Wiley India, New Delhi, 2010.
3. Next Big Thing Is Really Small: How Nanotechnology Will Change the Future of Your Business, Jack Uldrich, Deb Newberry, Crown Business Publications, 2003.

Online Resources:

1. www.nano.gov
2. www.science.doe.gov/nano
3. www.nnin.org

MM1331 **3-0-0 (3)**

Special Steels

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the strengthening mechanisms to enhance the properties of steels
CO-2	Differentiate between the properties of various special steels and their applications
CO-3	Evaluate the principles of micro-alloying and thermomechanical processing of steels
CO-4	Analyze the problems associated with heat treatment of tool steels and ultrafine grained steels
CO-5	Describe the challenges associated with developing nuclear grade steels

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
CO-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
CO-3	-	-	-	-	3	-	2	-	-	-	-	-	-	2	3	-
CO-4	-	-	-	-		-	-	-	-	-	-	-	-	-	2	-
CO-5	-	-	-	-	3	-	-	-	-	-	-	-	-	-	2	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

General Introduction: Properties and importance of various steels.

Review of strengthening mechanisms applicable to steels: Grain refinement, solid solution, precipitation, dispersion of second phases, martensite, twinning, workhardening**.**

Development of various steels: Principles of alloying, heat treatment and thermomechanical processing in steels. Production of dual phase steels, TRIP steels, TWIP steels; bainitic steels, IF steels, HSLA &advanced high strength low alloy steels,maraging steels, stainless steels, power plant steels, nuclear steels, high nitrogen stainless steels, tool steels, ultrafine grained steels.Non-equilibrium processing of steels.

Structure: Property correlations in various steels. Applications – structural, consumer, automotive, Nuclear and aerospace industries.

Learning Resources:

Text Books:

1. W.C. Leslie, Physical Metallurgy of Steels, Tech Books, 1991. .
2. F.B. Pickering, Physical Metallurgy and Design of Steels, Applied Science Publishers, 1978.
3. H.K.D.H. Bhadeshia, Bainite in Steels-Transformations, Microstructure and Properties, CUP, 2001.

Reference Books:

1. George Adam Roberts, Richard Kennedy, G. Krauss, Tool Steels, 5th Ed., ASM, 1998.

2. Albert M. Hall, Introduction to Today's Ultrahigh-strength Structural Steels, ASTM Special Technical Publication, 1973.

Other Suggested Readings:

1. R.F. Decker, Source Book on Maraging Steels, ASM, 1979.

MM1332 **3-0-0 (3)**

Creep, Fatigue and Fracture

Pre-Requisites: None

Course Outcomes:

CO-1	Classify deformation and fracture behaviour of materials at room and high temperature
CO-2	Determine theoretical and experimental fracture strength of materials through EPFM, CTOD and J-integral
CO-3	Predict the life of materials under fatigue loading
CO-4	Select metals and alloys for high-temperature applications

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3
CO-2	3	-	-	1	-	-	-	-	-	-	-	-	-	2	-	3
CO-3	3	-	-	2	-	-	-	-	-	-	-	-	-	2	-	3
CO-4	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Concepts of Stress, Strain and Fracture: Analysis of stresses and strains, Principal stresses and strains. Stress / Strain Invariants, Theories of Failure, Various yield criteria, Theoretical cohesive strength of metals, defects and stress concentration, stress due to crack inside a large plate, Energy balance during propagation of crack, concept of critical stress to propagate crack, Griffith theory, Common causes of engineering fracture, Fractography, Microscopic fracture modes, Fractographic observation of cleavage/brittle, quasi-cleavage and ductile/dimple fracture.

Fracture Mechanics: Concept of fracture, Classification of fracture, Mechanism of ductile and brittle fracture, Strain energy release rate, Modes of fracture, Stress intensity factor, Fracture toughness, Determination of fracture toughness (KIc), Plasticity at the crack tip, Orowan correction, Irwin's modification, Plastic zone shape and size, effect of constraint, plane stress, plane strain, thickness effect, CTOD, J integral.

Fatigue: Fatigue testing and its significance, S-N curve, HCF, LCF, Goodman diagram, fatigue limit, Paris law, Miner's rule, mechanism of fatigue failure, effect of variables on fatigue properties.

Creep: High temperature materials problem, Temperature dependent mechanical behavior, Creep test, Creep curve, Creep properties of metals, Structural change during creep, Creep mechanisms, Stress-rupture test, Deformation and fracture at elevated temperature, Prediction of long time properties, LMP, Creep resistant materials, Effect of metallurgical variables on creep.

Learning Resources:

Text Books:

1. Mechanical Behavior of Materials, M.A. Meyers and K.K. Chawla, Prentice Hall Inc., 1999.
2. Fracture Mechanics- Fundamentals and Applications, T. L. Anderson, 3rd Edition, CRC Press, 2011.

Reference Books:

1. Deformation and Fracture Mechanics of Engineering Materials, R. W. Hertzberg, 4th Edition, John Wiley & Sons Inc., 2012.
2. Mechanical Metallurgy, G. E. Dieter, 3rd Edition, McGraw-Hill, 2013.
3. Fundamentals of Creep in Metals and Alloys, Michael Kassner, 2nd Edition, Elsevier Science, 2009.

MM1334 **3-0-0 (3)**

Materials Characterization

Pre-Requisites: PH1161, CY1161, MM1201

Course Outcomes:

CO-1	Understand the principles of optical and electron microscopy.
CO-2	Explain the principles of XRD for materials characterization.
CO-3	Analyses thermal reactions using thermal analysis data.
CO-4	Select a suitable characterization technique for microstructural and compositional analysis

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
CO-2	3	3	–	–	–	–	–	–	–	–	–	–	–	1	1	3
CO-3	3	–	–	2	–	–	–	–	–	–	–	–	–	1	1	3
CO-4	3	-	-	2	–	–	–	–	–	–	–	–	–	1	1	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Optical microscopy: Fundamental of optical Microscope, Basic concept of imaging, Sample preparation.

Electron microscopy (EM): Fundamentals of SEM, EBSD and TEM, Concept of Scattering and Diffraction Electron source, Electromagnetic lens, Different imaging techniques principle of image formation in SEM and TEM, Effect of different parameter on imaging, Advantages, limitations of OM, SEM, EBSD and TEM, Sample preparation methods.

X-Ray diffraction: Basic concept of X-rays, X-Ray diffraction methods, Structure factor, Determination of crystal structure, Phase identification, Determination of lattice strain and crystallite size.

Surface characterization techniques: EDS, WDS, XRF, XPS and AES

Thermal analysis techniques: TGA, DSC, DTA, TMA and construction of phase diagram

Learning Resources:

Text Books:

1. Materials Characterization Techniques, S Zhang, L. Li and Ashok Kumar,CRC Press, 2008.
2. David B. Williams, C.Barry Carter, Transmission Electron Microscopy,Textbook for Materials Science, Springer, 2009, 2nd Edition.
3. An Introduction to Material Characterization, Khangaonkar P R, Penram Intl. Publishing (India) Pvt. Ltd,mumbai,2010.
4. Elements of X-Ray Diffraction, B.D.Cullity and S.R.Stock, 3rd Edition, Prentice Hall, NJ, 2001.

Reference Books:

1. Scanning electron microscope (SEM) instrumentation: Scanning Electron Microscopy and X-Ray Microanalysis. Springer, Goldstein JI, Newbury DE, Michael JR, Ritchie NW, Scott JH, Joy DCNew York, NY, 2018, 4th Edition.
2. Practical of Electron Microscope in material science: Electron Diffraction in the Electron Microscope- J. W. Edington, (Philips Technical Library) Macmillan Education UK (1975)
3. Practical of Electron Microscope in material science: J Interpretation of Transmission Electron Micrographs - J. W. Edington, (Philips Technical Library) Macmillan Education UK (1975)

Other Suggested Readings:

1. NPTEL Courses
2. MIT Open Course Ware, etc.

CH1328 **3-0-0 (3)**

Polymer Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the polymerization reaction mechanism & kinetics
CO-2	Identify suitable processing method for a given polymer
CO-3	Choose additives for polymers, blends
CO-4	Characterize polymers using different techniques

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO-1	3	1	1	1	-	-	-	-	-	-	-	-	3	2	1	-
CO-2	2	1	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO-3	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO-4	2	-	2	-	-	-	-	-	-	-	-	-	2	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction and Classification of Polymers: Thermoplastics, Thermosets, Natural polymers, Monomers used for polymer synthesis, Linear, Branch, Cross Linked Polymers, Addition polymers- kinetics, synthesis and reactions, Condensation polymers- kinetics reaction and processes, Polymerization Techniques - Emulsion polymerization and Suspension polymerization, Interfacial Polymerization with their merits, Ewart Kinetics for emulsion polymerization.

Polymer processing & manufacturing methods: Polymer additives, compounding, Fillers, plasticizers, lubricants, colorants, UV stabilizers, fire retardants and antioxidants. Extrusion process, Twin and Single Screw extrusion, Blow moulding, injection moulding, Wet and Dry spinning processes, thermoset moulding. Manufacturing of polymers: flow-sheet diagrams, properties & applications of PE, PP, PS, Polyesters, Nylons, ABS and PC

Polymer properties and characterization techniques: Factors influencing the polymer properties, Molecular Weights, Polydispersity Index, Different Methods of determination of Molecular weight, Effect of Molecular weight on Engineering Properties of Polymers, Viscoelastic behavior of plastics; Time - temperature superposition; Stress-strain behavior; fracture; creep; hardness; impact behavior; Basics of polymer rheology; Permeability; electrical; optical and flammability properties, Thermodynamics of Polymer Mixtures, ASTM and ISO methods for testing of polymers. Characterization techniques- DSC, TGA, TMA, DMA, UV visible, FTIR, NMR, SEM, TEM, optical microscopy, XRD

Learning Resources:

Text Books:

1. Fried J R, Polymer Science and Technology, Prentice Hall of India Pvt. Ltd., New Delhi, 2000, Eastern Economy Edition.
2. Premamoy Ghosh, Polymer Science and Technology, Tata McGraw Hill Publishing Company, New Delhi, 2010, 3rd Edition.

Reference Books:

1. R. Sinha, Outlines of Polymer Technology: Manufacture of Polymers, Prentice Hall of India Pvt. Ltd., New Delhi, 2002.
2. George Odian, Principles of Polymerization, John Wiley & Sons, Inc., 2004.
3. V R Gowariker, Polymer science, New Age International Publishers, 2019, 3rd Edition.

Online Resources:

1. https://nptel.ac.in/courses/103/106/105106205/
2. https://nptel.ac.in/courses/103/107/103107139/

MM1421 **3-0-0 (3)**

Physical Metallurgy of Non-Ferrous Metals and Alloys

Pre-Requisites: **MM1201**

Course Outcomes:

CO-1	Explain the structure-property correlations in non-ferrous metals and alloys.
CO-2	Analyze the phase diagrams of non-ferrous alloys.
CO-3	Explain the heat treatment techniques applied to non-ferrous systems.
CO-4	Select a non-ferrous alloy for a specific application.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	2	2	2	–	–
CO-2	3	2	–	–	–	–	–	–	–	–	–	2	–	2	–	–
CO-3	3	–	–	–	–	–	–	–	–	–	–	–	3	2	–	–
CO-4	3	2	1	–	–	–	–	–	–	–	–	2	–	–	–	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Aluminium and its alloys: Classification and designation of Aluminium Alloys, Non-heat treatable, Wrought Aluminium Alloys, Heat treatable Wrought and Cast Aluminium Alloys, Al-Cu, Al-Zn, Al-Li, Al-Si alloys with their phase diagrams, Compositions, heat treatments, properties and applications.

Magnesium and its alloys: Classification of Magnesium Alloys, Wrought and Cast magnesium Alloys with their Phase Diagrams, Compositions, heat treatments, properties, and applications.

Titanium and its alloys: Classification of Titanium Alloys, Compositions, heat treatments, properties, and applications.

Nickel and its alloys: Ni-Cr alloys, Ni-Al alloys, Ni-Cr-Al alloys, Ni-Cr-Al-Ti alloys Ni base super alloys phase diagram heat treatment properties and its applications,

Introduction to super-alloys: Nickel base Super alloys, strengthening mechanism of Ni base alloys (Solid-solution strengthening Precipitation strengthening, Carbide strengthening etc., Explanation of Anti-phase boundary energy, Lattice mismatch, Coarsening of gamma prime precipitates, Fe base super alloy and Co base super alloys new development, phase diagram alloying additions, properties, Advantages and disadvantages, Oxidation and corrosion resistance, long time phase stability.

Copper and its alloys: Copper-Zinc and Copper-Tin Phase Diagrams, Brasses and Bronzes Compositions, heat treatments, properties, and applications.

Lead, Zinc and Tin and their alloys: Compositions, heat treatments, properties, and applications. Babbitts (Antifriction alloys): Compositions, heat treatments, properties, and applications.

Precious metal & their alloys: Silver, Gold, Platinum, Palladium & their alloys. Iridium, Osmium, Rhodium, Ruthenium & their electrical applications.

Rare metals and their alloys: Characteristics and mechanical properties of these alloys.

Learning Resources:

Text Books:

1. J. Polmear, Light Alloys, 5th Edition, Elsevier, 2017
2. Y. Lakhtin, Engineering Physical Metallurgy, CBS Publishers, 1998.
3. Donald S Clark, Wilbur R Varney, Physical Metallurgy for Engineers, 2nd Edition, Van Nostrand, Reinhold Company, 1989.
4. Sidney H Avner, Introduction to Physical Metallurgy, 2nd Edition, McGraw-Hill, 1997.

Reference Books:

1. Metals Handbook–Vol.2: Properties and Selection- Non-ferrous alloys and Pure Metals, ASM, 2014.
2. Charlie R Books, Heat Treatment- Structure and Properties of Non-ferrous Alloys, ASM,1982.

Other Suggested Readings:

1. https://www.phase-trans.msm.cam.ac.uk/2003/nickel.html
2. https://www.youtube.com/watch?v=cR3rsPautR8

MM1423 **3-0-0 (3)**

Materials Selection and Design

Pre-Requisites: MM1305, MM1334

Course Outcomes:

CO-1	Discuss materials selection criteria for engineering applications.
CO-2	Describe the properties and applications of different classes of materials.
CO-3	Suggest thermal treatment methods for modifying microstructure and mechanical properties.
CO-4	Select materials for structural, functional and bio applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	2	–	–	–	–	–	–	–	–	3	2	2	–
CO-2	3	–	–	2	–	–	–	–	–	–	–	–	3	–	–	–
CO-3	3	2	–	2	–	–	–	–	–	1	–	–	3	2	2	–
CO-4	3	2	2	2	–	2	–	–	–	2	–	–	3	2	2	–

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Materials world and Design: Introduction to materials in design, Evolution of engineering materials and materials in products, Engineering materials and their properties, Design process, types and tools of design, materials data for design, Analyzation of design product function, design objective, constraints and free variables, steps of material selection in design process.

Materials selection- Ashby method, material property charts, Materials selection strategy and procedure, material indices, materials selection procedure, the structural index, single and multiple constraints in material selection, conflicting objectives, Shape factors, limits to shape efficiency, exploring material-shape combinations, Materials indices that include shape factors, Hybrid materials designing, composites, Sandwich structures, Cellular structures, Segmented structures. Selection of materials and design of materials for various applications.

Materials processing: Processes classification and attributes, Processes selection steps, Materials processes- shape relations, Processes selection screening and ranking, Materials, and environments: Materials lifecycle, Energy-consuming characteristic of materials, Eco-attributes of materials, Eco selection of materials.

Materials and industrial design: The requirements pyramid, Product character and personality, Design considerations in the use of materials are quality control; selecting materials to optimize multiple properties; materials failure; long-term materials properties; materials behavior under extreme conditions; corrosion; discussion of design and materials selection strategy; processing and process selection strategy; process economics; life cycle thinking and eco-design; special topics.

Learning Resources:

Text Books:

1. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 2005.

2. J. G. Gerdeen, H. W. Lord and R. A. L. Rorrer, Engineering Design with Polymers and Composites, Taylor & Francis, 2005.
3. D.R. Askeland and P.P. Phule, The Science and Engineering of Materials, Thomson Brooks/Cole Publication, 4th edition, 2006.
4. P. L. Mangonon, The Principles of Materials Selection and Design, Prentice Hall International, Inc. 1999.

Reference Books:

1. M.F. Ashby, Engineering Materials, 4th Edition, Elsevier, 2005.
2. ASM Metals Handbook, Vol.20- Materials Selection and Design, ASM, 1997.
3. M. F. Ashby and K. Johnson, Materials and Design, Butterworth Publication, 2002

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/104/112104122/

MM1425 **3-0-0 (3)**

Surface Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain surface engineering principles for metallic and non-metallic substrates
CO-2	Compare surface modification processes
CO-3	Assess the quality of surface coatings
CO-4	Suggest suitable surface modification process to combat friction, wear, corrosion, and oxidation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	1	-	-	2	3	1	-
CO-2	3	-	-	-	-	-	-	-	-	1	-	-	2	2	1	-
CO-3	3	-	2	1	-	-	-	-	-	1	-	-	2	-	-	2
CO-4	3	-	2	1	-	1	1	-	-	1	-	1	2	-	1	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Scope of surface engineering; status of surface engineering. Surface modification processes – classification – substrate surface modification and coatings

Microstructural optimization and properties via surface engineering: Selective surface hardening-Flame and induction hardening, High energy beam hardening (electron and laser beam); Laser melting and shot-peening. Damage of the surfaces by corrosion and wear; Wear mechanisms and categories of wear; Methods to control wear and corrosion, Material/process selection.

Surface chemistry optimization via surface engineering: Diffusion coatings - Carburizing, Nitriding, Carbonitriding, Nitrocarburizing, Cyaniding, Pack-cementation (Aluminizing, Siliconizing, Chromizing, Boronizing); Phosphate coatings, Chromate coatings, Anodizing, Micro Arc Oxidation; Oxidation Treatments; Plasma based surface modification processes; Ion-implantation and Laser alloying. Organic coatings, ceramic coatings, Hot Dip coatings, Electroplating and electroless plating, Weld overlay coatings, Thermal spray coatings (Arc spray, plasma spray, Flame spray, HVOF, Detonation spray), Cladding.

Recent and emerging trends in surface engineering: Physical vapour deposition (PVD), Chemical vapour deposition (CVD), Evaporation, Sputtering, Ion plating. Use of Laser and plasma in surface engineering. Surface modification by directed energy beams. Surface modification by Friction stir processing: Surface composites. Nano-composite coatings/surfaces; Nano-engineered coatings, Diamond like coatings (DLC), Sol Gel coatings, Novelty of surface composition and microstructure, Designing of surface engineering processes, Specific industrial applications.

Characterization and evaluation of coatings: Wear testing and corrosion testing. Adhesion testing, mechanical testing of surface coatings

Learning Resources:

Text Books:

1. J. R. Davis, Surface Engineering for corrosion and wear resistance, ASM International, 2001.
2. J. R. Davis, Surface hardening of steels-understanding the basics, ASM International, 2002.
3. I.M. Hutchings, Philip Shipway, “Tribology – Friction and wear of engineering materials, 2017.

Reference Books:

1. ASM Metal Handbook, Vol 5, Surface Engineering, ASM Int., 2004.
2. K. G. Budinski, Surface Engineering for Wear Resistance, Prentice Hall, New Jersey, 1998.

Other Suggested Readings:

1. https://archive.nptel.ac.in/courses/113/105/113105086/
2. https://archive.nptel.ac.in/courses/112/107/112107248/

ME1330 **3-0-0 (3)**

Finite Element Method

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply finite element method to solve problems in solid mechanics and heat transfer.
CO-2	Solve problems in one dimensional structures including trusses, beams and frames.
CO-3	Formulate FE characteristic equations for two dimensional elements and analyse plane stress, plane strain, and axi-symmetric and plate bending problems.
CO-4	Solve the finite element formulations using MATLAB.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	2	-	-	3	-	-	-	-	-	-	2	2	2	-	-
CO-2	3	3	2	2	3	-	-	-	-	-	-	2	2	2	-	-
CO-3	3	3	2	2	3	-	-	-	-	-	-	2	2	2	-	-
CO-4	2	2	-	-	3	-	-	-	-	-	-	2	2	3	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview of the course, examination and evaluation patterns, history and basic concept of finite element method and direct FEM.

Fundamental concepts: Calculus of variation and solving differential equations, Ritz method, Galerkin method, least squares, collocation and subdomain methods, Case studies for Ritz and Galerkin methods, Ritz FEM formulation, Galerkin FEM formulation.

One-Dimensional Problems: Finite element formulation for 1-D problems, elimination method, penalty method, computer implementation and case studies.

Trusses: Introduction, fem formulation, plane trusses, three dimensional trusses, frames and case studies.

Two-Dimensional Problems: Finite element formulation for 2-D problems, constant strain triangle, various elements, iso parametric, sub parametric and super parametric elements, interpolation functions, computer implementation and case studies.

Numerical Integration and 2-D problems of Elasticity: Introduction to numerical integration, two dimensional integrals, plane stress, plane strain, axisymmetric, plate bending problems.

Thermal Applications: Two - dimensional heat conduction analysis, formulation of functional, element matrices and case studies.

Fluid Mechanics Applications: Stream function formulation, velocity potential formulation and torsional analysis of a prismatic bar.

Three Dimensional Problems: Finite element formulation for 3-D problems, mesh preparation, hexahedral elements, shell elements and case studies.

Learning Resources:

Text Books:

1. Seshu P., Textbook of Finite Element Analysis, PHI, 2009.
2. Reddy, J.N., Finite Element Method in Engineering, Tata McGraw Hill, 2007.
3. Zeincowicz, The Finite Element Method for Solid and Structural Mechanics, 4th Edition, Elsevier 2007.

MM1433 **3-0-0 (3)**

Metal Forming

Pre-Requisites: MM1305

Course Outcomes:

CO-1	Summarize the stress-strain relationship.
CO-2	Describe deformation behavior, yield criteria and metal working.
CO-3	Differentiate metal forming processes of forging, rolling, extrusion, and drawing.
CO-4	Classify defects of forging, rolling, extrusion and drawing.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	2	3	-	-	-	-	-	-	-	-	3	-	3	-	2
CO-2	3	2	-	-	-	-	-	-	-	-	-	-	1	3	-	2
CO-3	3	-	-	-	-	-	-	-	-	-	-	-	3	3	1	-
CO-4	3	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Concepts of Stress and Strain: Review of two-dimensional stress and strain, state of stress in three dimensions, Stress tensor, Invariants, Mohr's circle for 3-dimensional state of stress, strain at a point Mohr's circle for strain, Hydrostatic & Deviatory components of stress, Elastic stress strain relations.

Elements of theory of plasticity; Flow curve, True stress & true strain, Yield criteria for ductile metals, Von Misses & Teresa yield criteria, combined stress tests. The yield locus, Anisotropy in yielding.

Mechanics of metalworking, Analysis methods, Hot and cold working: Classification of forming processes variables in metal forming and their optimization, Flow stress determination, Hot working, Cold working, Strain rate effect, Friction and lubrication, Deformation zone geometry, Workability, Residual stresses.

Forging: Classification of Forging Processes, Forging Equipment, Forging in Plane Strain, Open-Die Forging, Closed-Die Forging, Calculation of Forging Loads in Closed-Die Forging, Forging Defects, Residual Stresses in Forgings

Rolling: Classification of Rolling Processes, Rolling Mills, Hot-Rolling, Cold-Rolling, Rolling of Bars and, Shapes, Forces and Geometrical Relationships in Rolling, Simplified Analysis of Rolling Load: Rolling Variables, Problems and Defects in Rolled Products, Rolling-Mill Control, Theories of Cold- Rolling, Theories of Hot-Rolling, Torque and Power.

Extrusion: Classification of Extrusion Processes, Extrusion Equipment, Hot Extrusion, Deformation, Lubrication, and Defects in Extrusion, Analysis of the Extrusion Process, Cold Extrusion and Cold- Forming, Hydrostatic Extrusion, Extrusion of Tubing, Production of Seamless Pipe and Tubing, Defects in Extrusion.

Drawing: Introduction, Rod and Wiredrawing, Analysis of Wiredrawing, Tube-Drawing Processes, Analysis of Tube Drawing. Residual Stresses in Rods, Wires, and Tubes. Deep Drawing, Forming Limit Criteria, Defects in Formed Parts.

High Energy Rate Forming (HERF) Processes: Principle / important features of HERF processes, Advantages of HERF Processes, Limitations, Applications: Explosive Forming, Electrohydraulic Forming, Electromagnetic forming.

Flow forming and Severe Plastic Deformation techniques: Equal channel angular Pressing (ECAP), Accumulative roll bonding, High pressure torsion

Learning Resources:

Text Books:

1. G.E. Dieter, Mechanical Metallurgy, 3rd Edition, McGraw Hill, New York, 2013.
2. C. J. Richardson, Worked Examples in Metal Working, Institute of Metals, London, 1985.
3. Surender Kumar, Principles of Metal Working, 2nd Edition, Oxford & IBH, 2001.

Reference Books:

1. ASM Handbook, Vol. 14: Forming and Forging, ASM International, 2012.

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/106/112106153/
2. https://nptel.ac.in/courses/112/103/112103279/
3. https://nptel.ac.in/courses/112/107/112107250/

MM1435 **3-0-0 (3)**

Metallurgical Failure Analysis

Pre-Requisites: **MM1305**

Course Outcomes:

CO-1	Explain reasons for failure of materials.
CO-2	Differentiate fracture modes and failure mechanisms.
CO-3	Determine fracture toughness of materials.
CO-4	Predict life of materials under mechanical loading.
CO-5	Examine failure analysis through case studies.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-3	3	1	-	2	-	-	-	-	-	-	-	-	-	2	-	2
CO-4	3	2	2	2	-	-	-	-	-	-	-	-	-	2	-	2
CO-5	3	2	-	2	-	-	-	-	-	-	-	-	-	2	-	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Aims of failure analysis: Principal factors in the premature failure of metallic components and structures

Stages of analysis: collection of background data & selection of samples, preliminary examination of failed part (visual examination and record keeping), nondestructive testing, mechanical testing, selection, presentation and cleaning of fracture surface, macroscopic examination of fracture surface, microscopic examination of fracture surface, scanning electron microscopy. Tools and techniques in failure analysis.

Types of failures: Ductile, brittle, fatigue, creep, corrosion, wear etc., Failure under creep and fatigue, creep fatigue interaction, life estimation under creep and fatigue.

Fracture modes: Shear mode, cleavage mode, other fracture modes, factors affecting the ductile-brittle relationship, stress systems related to fracture of ductile and brittle metals: Pure loading systems-Tension, Torsion, Compression, Bending and Fatigue. Effect of stress concentration, study of fractograph of metallic components.

Determination of fracture type: Ductile and brittle fracture, failure due to Distortion, Fatigue, Creep, Wear, Corrosion, and Erosion. Elevated temperature failure, stress rupture failure and complex failure. Stress corrosion cracking, hydrogen embrittlement, liquid metal embrittlement, chemical analysis, simulated service testing.

Mixed mode and fatigue failures: Failure mechanisms, Embrittlement phenomena, environmental effects, Failures due to faulty heat treatments, Failures in metal forming and welding

Prevention of failures: Case studies in failure analysis, Case histories of component failures

Learning Resources:

Text Books:

1. Fatigue of Materials, S. Suresh, Cambridge University Press, 2nd Edition, 1998.
2. Deformation and Fracture Mechanics of Engineering Materials, Richard W. Hertzberg, John Wiley & Sons, New York, 5th Edition, 2012.

Reference Books:

1. ASM Metals Hand Book, Failure Analysis and Prevention, Vol. 11, 10th Edition, ASM International, 2002.

MM1437 **3-0-0 (3)**

Non-Destructive Testing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the basic principles of non-destructive testing (NDT) methods.
CO-2	Differentiate between NDT methods.
CO-3	Identify suitable surface NDE methods for defect detection.
CO-4	Discuss the necessary precautions against radiation hazards.
CO-5	Interpret the defects in engineering components using NDT methods.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO-3	3	-	-	-	-	-	-	-	-	-	-	-	2	2	-	3
CO-4	3	-	-	-	-	2	3	-	-	-	-	-	1	-	-	3
CO-5	3	3	-	3	-	-	-	-	-	-	-	-	3	2	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to NDT: Classification of NDT processes; advantages and limitations of NDT

Eddy Current Testing and Liquid penetrant testing: Principle, Advantages, Limitations, and applications of eddy current testing; Liquid penetrant testing - Principle, Advantages, Limitations and applications.

Magnetic Particle Testing: Principle, Procedure, Magnetic media, Methods to generate magnetic fields, Method of De-Magnetization, Interpretation of indications, Advantages, limitations, and applications.

Radiographic Testing: Principle, Gamma radiography, X-ray radiography and Neutron radiography, Imaging modalities, Radiograph Interpretation, Precautions against radiation hazards.

Ultrasonic Testing and Acoustic Emission Testing: Principles of ultrasonic testing, Ultrasonic propagation, Test techniques – normal and angle beam, Probes, Transducers, Applications, Advantages, and limitations of ultrasonic testing. Acoustic emission testing – principle, sources of acoustic emission, acoustic emission signal parameters, industrial applications

Learning Resources:

Text Books:

1. Practical Non-Destructive Testing, Baldev Raj, T. Jayakumar, M. Thavasimuthu, Narosa Publishing House, 2014.
2. Non-Destructive Testing Techniques, Ravi Prakash, New Age International Publishers, 1st revised edition, 2010.

Reference Books:

1. Non-Destructive Testing - Theory, Practice and Industrial Applications, Wong B Stephen, LAP
2. Lambert Academic Publishing, USA, 1st edition, 2014.
3. Non-Destructive Test and Evaluation of Materials, J. Prasad and C. G. K. Nair, Tata McGraw-Hill Education, 2011, 2nd edition.
4. ASM Metals Handbook, Non-Destructive Evaluation and Quality Control, American Society of Metals, Metals Park, Ohio, USA, Volume-17.
5. Charles, J. Hellier, Handbook of Non-destructive evaluation, Charles, J. Hellier, McGraw Hill, New York, 2001.
6. Paul E Mix, Introduction to Non-destructive testing: a training guide, Wiley, 2nd Edition New Jersey, 2005.

Other Suggested Readings:

1. www.ndt.edu
2. www.nde-ed.org

MM1439 **3-0-0 (3)**

Pollution and its Control in Metallurgical Industries

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the sources of pollution from metallurgical industries.
CO-2	Quantify pollutants from process industries.
CO-3	Propose methods for prevention of pollution.
CO-4	Perform case studies on pollution control in metallurgical industries.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	-	-	-	-	1	2	1	-	-	-	-	2	-	-	-
CO-2	2	-	-	-	-	-	2	-	-	-	-	-	2	-	-	2
CO-3	2	-	2	-	-	2	2	1	-	-	-	-	2	-	-	-
CO-4	2	-	-	-	-	1	2	1	-	-	-	-	2	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Principles of Pollution: Definition, Classification of pollution methods, Qualification techniques to identify pollution, Quantification methods of pollution, Standards and Rules applicable to pollution.

Sources of Pollution: Different kinds of pollutants and their identification techniques, Pollution control: Established pollution control and measures, Techniques to eradicate/minimize pollution, Prevention of pollution by means of instruments and design.

Pollution in Industries: Iron and Steel industries- causes, identification and control; Smelting industries-causes, identification and control, Sponge iron industries-causes, identification and control, Non-ferrous smelting industries-causes, identification and control, Foundries: causes, identification and control, Rolling Mills: acids/chemicals used during pickling, Cooling lubricants, etc., Welding industries: Fumes, poisonous gases and Slag disposal. Standards and Regulations of pollution in India.

Learning Resources:

Text Books:

1. R C Gupta, Energy and Environmental management in Metallurgical industries, PHI, 2012.
2. B Mazumdar, M K Mishra, Managing Wastes from Aluminum Smelter Plants, Woodhead Publishers, 2011.
3. S C Bhatia, Pramod Kumar, Sarvesh Devraj, Industrial Pollution and its Control, Woodhead Publishers, 2017.

Reference Books:

1. Industrial Safety and pollution control handbook: National Safety Council and Associate publishers Pvt. Ltd, Hyderabad, 1993.
2. Kreith F. and Tchobanoglous G.: Handbook of Solid Waste Management, 2 Ed; Mc Graw Hill, 2002.

3. Pasquale Cavaliere, Ironmaking and Steelmaking processes - Greenhouse emissions, control and reduction, Springer, 2016.
4. G L Datta, K B De, A Nag, Foundry Moulding Materials and Pollution, New Age Publishers, 2005.
5. Bhaskar Nath, Georgi Stefanov Cholakov, Pollution Control Technologies, Vol III, EOLSS Publishers, 2009.

Other Suggested Readings:

1. https://nptel.ac.in/courses/123/105/123105001/

MM1422 **3-0-0 (3)**

Materials for Bio-Application

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify materials requirements for bio-applications.
CO-2	Classify biomaterials.
CO-3	Assess a material for bio-applications.
CO-4	Conduct case studies on materials selection for bio-applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO-3	3	-	-	-	-	2	-	-	-	-	-	-	-	-	2	-
CO-4	3	-	3	3	-	-	-	-	-	-	-	3	-	2	1	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Overview of biomaterials: Historical developments, impact of materials.

Classification biomaterials: Metallic implant materials, ceramic implant materials, polymeric implant materials and composites as biomaterials, Grafts.

Cell Structure and properties of biomaterials: Bone structure, Bone properties, Proteins, Bacteria structure, Antibacterial assay, Biocompatibility, Cell-material Interaction: In vivo testing, Cell-material interaction, Cell-signalling, in vitro testing, Cytotoxicity, Clinical trials, Tissue Engineering.

Applications: Case studies on use of biomaterials for various applications.

Learning Resources:

Text Books:

1. J. Park and R.S. Lakes, Biomaterials an introduction, 3rd Edition, Springer, 2007.
2. Ed. R. D. Ratner, A. S. Hoffman, F. J. Schoen and J. E. Lemons, Biomaterials Science, An Introduction to Materials in Medicine, 2013.

Reference Books:

1. B. Basu, D. Katti and Ashok Kumar; Advanced Biomaterials: Fundamentals, Processing and Applications; John Wiley & Sons, Inc., USA, 2009.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/108/113108071/

MM1424 **3-0-0 (3)**

Materials for High Temperature Applications

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the principles of oxidation of metals and alloys.
CO-2	Classify materials for high temperature applications.
CO-3	Explain mechanisms of creep, thermal fatigue, oxidation, and hot corrosion.
CO-4	Select materials for high temperature applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	2	-	-	-	-	-	-	-	-	-	-	3	2	2	-
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO-3	3	2	-	-	-	-	-	-	-	1	-	-	3	2	2	-
CO-4	3	2	2	-	-	2	-	-	-	2	-	-	3	2	2	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Mechanisms of oxidation: Oxidation of pure metals, Oxidation of alloys, High Temperature Oxidation theory, Reactions of metals in mixed environments,

Creep: Creep phenomena, various stages of creep, Andrade's analysis, metallurgical factors influencing creep, stress rupture test, structural changes during creep, activation energy for creep, Factors influencing functional life of components at elevated temperatures, effect of stress, temperatures and strain rate, representation of engineering creep data, Prediction of long-time properties, Creep-resistant alloy design.

Promising materials for high temperature applications: Heat resistance steels, Stainless steels, Super alloys, Titanium alloys, Intermetallics, Ceramics, composites, Refractory metals and alloys. High temperature Polymers. Testing of materials for high temperature applications.

Case studies: Power plant materials, boiler materials, turbine materials, steam engine, jet engines and gas turbine materials.

Learning Resources:

Text Books:

1. Materials for High Temperature Engineering Applications, G.W. Meetham, M.H. Van de Voorde, Springer, 2000.
2. Fundamentals of Creep in Metals and Alloys, Michael E. KassnerMarı´a-Teresa Pe´rez-Prado, Elsevier, 2004.

Reference Books:

1. Introduction to creep, Institute of Materials, R.W. Evans, B Wilshire, 1993.
2. High Temperature Oxidation and Corrosion of Metals, David young, Elsevier Publications, 2016, 2nd Edition.
3. The Super alloys: Fundamentals and Applications, Roger C. Reed, Cambridge university press, 2006.

MM1426 **3-0-0 (3)**

Advanced Engineering Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the need and requirements for advanced materials development.
CO-2	Explain the unique structures of advanced materials.
CO-3	Discuss principles and applications of bulk metallic glasses and meta materials.
CO-4	Differentiate high entropy alloys from conventional alloys.
CO-5	Suggest an advanced material for an industrial application.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	2	-	-	-	-	-	-	-	-	1	-	2	1	-
CO-2	3	-	1	-	-	-	-	-	-	-	-	-	-	2	1	-
CO-3	3	-	1	-	-	-	-	-	-	-	-	-	-	2	1	-
CO-4	3	-	1	-	-	-	-	-	-	-	-	-	-	2	1	-
CO-5	3	-	2	3	-	-	-	-	-	-	-	1	-	2	1	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: general introduction to material properties, requirements for materials with exotic properties, advances in materials development, new classes of advanced materials

Bulk Metallic glasses: Definition, Fundamental concepts, Types, Criteria for glass formation and stability, Mechanical and Functional properties, Processing microstructure and properties, Disadvantages, Examples, and Applications.

High Entropy Alloys: Introduction, Definition, Thermodynamic concepts of HEAs/ Phase Formation Rules, Core effects, Microstructure and Mechanical Properties, Prediction of Structure and Phase Transformations.

Metamaterials: Definition, Advantages over other materials, Types and synthesis, General Theory on Artificial Metamaterials, Experiments and Applications of Metamaterials.

Quasicrystals: Definition, Introduction, structures and symmetries, Fundamental concepts, Quasi-crystallography, Production, Defects, Elastic and Plastic Properties, Mechanical Properties, Magnetic Properties, Recent Developments, Applications. Any other relevant advanced materials.

Learning Resources:

Text Books:

1. Bulk Metallic glasses, C. Suryanarayana, A. Inoue, CRC Press, 2nd ed., 2017.
1. High-Entropy Alloys, B.S. Murty, J.W. Yeh, S. Ranganathan, Butterworth-Heinemann publications, 2014.

2. Metamaterials: Theory, Design, and Applications, Tie Jun Cui, David Smith, Ruopeng Liu, Springer US publications, 1st ed., 2010.
3. Quasicrystals: An Introduction to Structure, Physical Properties and Applications, J.B. Suck, M. Schreiber, P. Häussler, Springer-Verlag Berlin Heidelberg publications, 1st ed., 2002.
4. Fundamentals of Radiation Materials Science: Metals and Alloys, Gary S. Was, Springer International Publication, 2017.

Reference Books:

1. Bulk Metallic Glasses: An Overview, Michael K. Miller, Peter Liaw, Springer US publications, 1st ed., 2008.
2. High-Entropy Alloys Fundamentals and Applications, Michael C. Gao, Jien-Wei Yeh, Peter K. Liaw, Yong Zhang, Springer International Publishing Switzerland 2016.
3. Metamaterials: Physics and Engineering Explorations, Nader Engheta, Richard W Ziolkowski, Wiley-IEEE Press, 2006.
4. Quasicrystals, Volume 3, Takeo Fujiwara, Yasushi Ishii, Elsevier Science publications, 1st ed., 2007.
5. New Geometries for New Materials, Eric A. Lord, Alan L. Mackay, S. Ranganathan, Cambridge University Press, 2006.

MM1428 **3-0-0 (3)**

Refractory and Rare Metal Extraction

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify ore break down techniques.
CO-2	Explain concentration techniques for leach solutions.
CO-3	Design flow sheets for extraction rare and refractory metals.
CO-4	Describe high temperature reduction techniques.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
CO-3	3	-	2	-	-	-	-	-	-	-	-	-	1	1	-	-
CO-4	3	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Ore breakdown techniques: Ore breakdown of different refractory and rare metals by acid and alkali leaching techniques, breakdown by chlorination, fluoride breakdown processes.

Purification processes: Purification techniques, purification of uranium by solvent extraction and ion exchange, purification of thorium by ion exchange techniques, production by fluidized bed processes, process design, Dry way conversion processes.

Metal production techniques: Production of uranium tetra fluoride and thorium fluoride, Metal production by high temperature reduction techniques, metal powder and sponge production techniques, Molten salt electrolytic processes, Electrolysis of beryllium chloride, production of uranium metal by electrolysis, zirconium electrolysis from chloride-fluoride melt, iodide decomposition processes, flow sheets from ore to metal.

Learning Resources:

Text Books:

1. C.A. Hampel, Rare Metals Hand Book, Robert E. Krieger Publishing Company,1971.
2. H. S. Ray, R. Sridhar and K.P. Abraham, Extraction of Non-Ferrous Metals, Affiliated East –West, 1985.
3. W. D. Jamrack, Rare Metal Extraction by Chemical Engineering Techniques, Pergamon, 1963.
4. R. Raghavan, Extractive Metallurgy of Non-Ferrous Metals, Vijay Nicole Imprints Private Limited, 2016.

Reference Books:

1. Fathi Habashi, Hand Book of Extractive Metallurgy, Vols I-IV, Wiley-VCH Breach, 1997.
2. Seshadri Seetharaman (Ed), Treatise on Process Metallurgy, Volume 3: Industrial Processes, Elsevier, 2014.

MM1430 **3-0-0 (3)**

Recycling of materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify types and sources of metallurgical waste.
CO-2	Discuss the impact of metallurgical waste on environment and economics.
CO-3	Suggest methods for conservation of energy in metallurgical processes.
CO-4	Comprehend recycling of metallurgical waste.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	1	2	-	-	-	-	-	2	-	-	-
CO-2	3	-	-	-	-	3	3	-	-	-	-	-	2	-	-	-
CO-3	3	-	2	-	-	2	2	-	-	-	-	-	2	-	-	-
CO-4	3	-	-	-	-	1	2	-	-	-	-	-	2	2	2	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Types of Metallurgical waste, Waste characterization, Energy conservation, Environmental issues, recycling, etc.

Metallurgical wastes: Primary and secondary solid wastes in metallurgical and powder industry, Generation of waste during primary processing of ores and beneficiation, Waste from extraction and refining processes, nuclear waste, Gaseous wastes in metallurgical operations, minimization techniques, precautionary measures.

Energy saving: Alternative routes of extraction of metals for energy saving. Direct reduction v/s Conventional route for steel making. Role of optimal selection of metal processing route, Conservation through protection of materials against decay, Waste heat recovery methods.

Environmental Protection: General concepts of environment, toxicology of metals, Stack gases of Electric Arc Furnaces and primary metal production processes, and methods for their beneficiation.

Recycling of Metals: Economical, technological, and environmental aspects of metal recycling (ferrous/non-ferrous), Economic uses of solid waste such of B.F. slag and fly ash & wastes from non-ferrous industry, Case study: Recycling of ferrous/non-ferrous metals, scraps, cans, cables, wires, electronics and computers waste.

Learning Resources:

Text Books:

1. S. Ramachandra Rao, Resource recovery and recycling from metallurgical wastes, Elsevier, 2006.
2. M. Kutz, Environmentally conscious materials and chemicals processing, John Wiley & Sons, 2007.
1. Ernst Worrell, Markus Reuter (Eds): Handbook of Recycling, Elsevier, 2014.
2. Donald L Stewart, James C Delay, Robert L Stephens: Recycling of Metals and Engineered Materials (Proceedings of the fourth international symposium), TMS Publications, 2000.

Reference Books:

1. F. Woodard, Industrial waste treatment handbook: Butterworth-Heinemann, 2001
2. H.F. Lund, Recycling Handbook, 2nd Edition, McGraw-Hill, 2000.

Other Suggested Readings:

1. https://nptel.ac.in/noc/courses/noc19/SEM1/noc19-ce06/

MM1432 **3-0-0 (3)**

Materials for Extreme Environments

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the principles of complex material-environment interactions.
CO-2	Apply the thermodynamic and metallurgical principles to choose the right material for combined high temperature, high pressure environments.
CO-3	Discuss the novel processing routes for emerging materials for extreme environments.
CO-4	Predict the plausible material failure mechanism for materials specific to nuclear industry.
CO-5	Recommend the suitable composition and microstructure for space and aviation applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	2	-	-	-	-	1	-	-	1	-	-	2	3	2	-
CO-2	3	2	1	-	-	-	-	-	-	1	-	-	3	3	2	-
CO-3	3	-	1	-	-	-	1	-	-	1	-	-	3	-	3	-
CO-4	3	1	2	1	-	-	-	-	-	1	-	2	3	2	-	3
CO-5	3	2	2	1	-	-	-	-	-	1	-	2	3	-	3	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Extreme environment -definition & types, conventional materials and their performance limits in extreme conditions, aspects and human safety, complex interactions between environment and materials – thermodynamic and kinetic aspects

Materials for energy: Next generation fast fission and fusion reactors – current status of materials and material challenges – high and ultra-high temperature applications, Materials for high temperature and high-pressure environments, materials for intense radiation and high energy particle impingement

Materials for space explorations and aviation: low Earth orbit – micrometeoroid, space debris, atomic oxygen, radiation and thermal cycling, hypersonic applications, complex environmental interactions due to high temperature, oxidizing conditions and high pressure, overview of conventional and emerging materials to meet the criteria: advanced metallic, ceramic, and composite materials.

Materials for marine and deep-sea technologies: design criteria for radiation and microbially induced material failures, extreme environment electronics

Emerging material synthesis, manufacturing, testing and characterization technologies: Nanomaterial technologies, additive manufacturing, novel composite materials technologies, advanced materials testing & characterization – AFM, HRTEM, APT, computational tools for material synthesis and optimization; testing – corrosion fatigue, SCC, creep-fatigue modelling and predictions, bio-fouling analysis.

Learning Resources:

Text Books:

1. Advanced Materials and structures for extreme operating conditions, Dr. Jacek J Skrzypek, Dr. Arthur W. Ganczarski, Haling Egner, Dr. Franco Rustichelli, Springer, 2008, 1st Edition.
2. Nanomaterials for Extreme environments, Rostislav A. Andrievski, Arsen V. Khatchoyan, Springer, 2016, 1st Edition.

Reference Books:

1. Ultra-high temperature ceramics: Materials for extreme environment applications (I , II & III), William G. Fahrenholtz, Eric J. Wuchina, Wiley, 2014.

MM1434 **3-0-0 (3)**

Smart Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify smart materials based on the general operational principles.
CO-2	Describe the principles and applications of piezoelectric and magneto strictive materials.
CO-3	Discuss the mechanism of shape memory, self-healing, and self-organizing materials.
CO-4	Select materials for thermo-chromic and photo-chromic applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-2	3	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-
CO-3	3	-	-	1	-	-	-	-	-	-	-	1	-	-	2	-
CO-4	3	2	-	1	-	-	-	-	1	-	-	1	-	-	2	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Overview of Smart Materials: Introduction and definition of Smart Materials, Principles of smart materials, input – output decision ability, Devices based on conductivity changes, Devices based on changes in optical response, Biological systems and smart materials, Devices based on magnetization, Artificial structures, surfaces, hetero structures, polycrystalline, amorphous, liquid crystalline materials.

Piezoelectricity and Magnetostriction: Principles of Piezoelectricity, Perovskite Piezoceramic Materials, Single Crystals vs Polycrystalline Systems, Piezoelectric Polymers, Principles of Magnetostriction, Rare earth Magneto strictive materials, Giant Magnetostriction and Magneto resistance Effect, Magnetorheological fluids, Electrorheological materials and their applications.

Electro-active Materials: Electronic Materials, Electro-active Polymers, Ionic Polymer Matrix Composites (IPMC)

Shape Memory Alloys: Shape Memory Effect, Shape Memory Alloys, Shape Memory Polymers, Self-Sensing Piezoelectric Transducers, Energy Harvesting Materials, Self-healing materials. Micro-electromechanical Smart Systems, Intelligent devices based on smart materials, Self-organizing nano materials.

Smart materials in drug delivery, Thermo-chromic and photo-chromic applications and hybrid and composite systems, Green materials and Energy materials.

Learning Resources:

Text Books:

1. Smart materials and new technologies, M. Addington, Schodek, L. Daniel, Architectural Press, 2005.
2. Smart Materials and Structures, M.V. Gandhi, B.S. Thompson, Chapman & Hall, 1992.
3. Smart Structures and Materials, B. Culshaw, Artech House, 2000.

4. Shape Memory Materials, D.I. Arun, P. Chakravarthy, R. Arockia Kumar, B. Santhosh, CRC Press, 2018.

Reference Books:

1. Smart Materials: Proceedings of the 1st Caesarium, Hoffmann, Karl-Heinz (Ed.), Springer, 1999.
2. Smart Materials – An Industrial Perspective, P. Nikhil Chandra, Mothi Krishna Mohan, Notion Press, 2021.
3. Encyclopedia of Smart Materials, Volumes 1-2, M. Schwartz, Willey, 2002.
4. Smart material systems, Smith C, Ralph, SIAM, 2005.
5. Smart Structures: Physical Behaviour, Mathematical Modelling and Applications, P. Gauenzi, Wiley Publishers, 2009.
6. Smart Material Systems and MEMS: Design and Development Methodologies, V. K. Varadan, K. J. Vinoy, S. Gopalakrishnan, John Wiley and Sons, 2006.

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/104/112104251/
2. https://nptel.ac.in/courses/113/105/113105081/

MM1436 **3-0-0 (3)**

3D Printing Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the basic concepts and importance of additive manufacturing
CO-2	Describe the principles, processes and advantages of additive manufacturing systems
CO-3	Apply the knowledge of additive manufacturing for various real-life applications
CO-4	Suggest mitigation techniques for additive manufacturing defects
CO-5	Discuss importance and future applications of additive manufacturing field

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	-	-	1	-	2	-	-	-	-	-	-	-	1	-	-	-
CO-2	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-
CO-3	-	-	1	-	1	-	-	-	-	-	-	-	1	-	2	-
CO-4	2	-	1	-	2	-	-	-	-	-	-	-	-	-	1	-
CO-5	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview, basic principles and advantages of additive manufacturing, procedure of product development in additive manufacturing, classification of additive manufacturing processes.

Generic AM process: CAD, conversion of STL, transfer to AM machine and STL file manipulation, machine setup, build, removal, distinction between AM and CNC machining, reverse engineering

Additive Manufacturing Processes: Z-Corporation 3D-printing, Stereolithography apparatus (SLA), Fused deposition modeling (FDM), Laminated Object Manufacturing (LOM), Selective deposition lamination (SDL), Ultrasonic consolidation, Material Jetting, Binder jetting

Powder bed fusion processes: Selective laser sintering (SLS), Laser engineered net shaping (LENS), Selective laser melting (SLM), Electron beam melting (EBM), materials, powder fusion mechanisms, powder handling challenges, powder recycling, defects

Direct energy deposition processes: DED process description, powder feeding, wire feeding, laser and electron-based deposition processes

Post-Processing in Additive Manufacturing: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques, applications of additive manufacturing in rapid prototyping, rapid manufacturing, rapid tooling, repairing and coating.

Future scope in Additive Manufacturing: Scope of AM in various fields, importance and applications.

Learning Resources:

Text Books:

1. C.K. Chua, K.F. Leong, C.S. Lim: Rapid prototyping- Principles and applications, 3rd Ed., World Scientific Publishers, 2010.
2. Gibson, I, Rosen D W., and Stucker B., Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010
3. Chee Kai Chua, Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications: Fourth Edition of Rapid Prototyping, World Scientific Publishers, 2014
4. A. Gebhardt: Rapid prototyping, Hanser Gardener Publications, 2003.

Reference Books:

1. Additive Manufacturing Processes, Editor: David L. Bourell, William Frazier, Howard Kuhn, and Mohsen Seifi, ASM Hand Book, Volume 24, ASM International 2020.

Other Suggested Readings:

1. https://additivemanufacturing.com/basics/
2. https://www.additivemanufacturing.media/.

Open Electives

MM1475 **2-0-0 (2)**

Metallurgy for Non-Metallurgists

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the characteristics and applications of metals and alloys.
CO-2	Explain different fabrication techniques.
CO-3	Correlate the microstructure, properties, processing and performance of materials.
CO-4	Select metal/alloy for engineering applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-2	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-3	1	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-4	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Metallurgy: Metals and Alloys classification, engineering applications of Metals/alloys.

Structure of Metals and Alloys: Nature of Metallic Bonding, Crystal Structures of Metals, Structure of Alloys, Imperfections in Crystals.

Mechanical Properties: Hardness, Tensile, Creep, Fatigue, Fracture.

Fabrication of metal products: Principles of Metal Casting, Metal Working, Powder Metallurgy, Metal Joining and Machining.

Engineering Alloys: Steel Products and Properties, Cast Irons, High Speed Steels, Stainless Steels, selective non-ferrous metals and alloys.

Learning Resources:

Text Books:

1. M. F. Ashby, Engineering Metals, Elsevier, 2005, 4th Edition.
2. R. Abbaschian, L. Abbaschian, R.E. Reed-Hill, Physical Metallurgy Principles, East-West Press, 2009.
3. V. Raghavan, Elements of Materials Science and Engineering- A First Course, PHI Publications, 2011, 5th Edition.

Reference Books:

1. S. Somiya, R. Balasubramaniam (Adapted): Calister's Materials Science and Engineering, Wiley India (P) Ltd, 2007, 7th Edition.

Other Suggested Readings:

1. https://archive.nptel.ac.in/courses/113/105/113105024/

MM1476 **3-0-0 (3)**

Fundamentals of Materials Processing Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify engineering materials.
CO-2	Discuss material processing techniques.
CO-3	Select a suitable processing technique for a given material and application.
CO-4	Explain surface engineering techniques and their engineering significance.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-2	1	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-3	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-4	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Engineering Materials: Metals and alloys, ceramics - structure and properties of ceramics, traditional ceramics, new ceramics, glass ceramics; polymers - fundamentals of polymers, thermoplastic and thermosetting polymers, elastomers; composite materials - classification of composite materials.

Fundamental Properties of Materials: Mechanical properties, physical, electrical and chemical properties of metals, polymers, ceramics and composites.

Metal Casting Fundamentals and Metal Casting Processes: Overview of casting technology, sand casting, other expendable-mold casting processes, permanent-mold casting processes, casting quality.

Particulate Processing of Materials: Powder metallurgy-characterization of engineering powders, production of metallic powders, conventional processing and sintering, alternative processing and sintering techniques, processing of ceramics, polymers and composites.

Metal forming and shaping: Rolling, forging, extrusion, drawing, sheet metal forming.

Materials Joining: Importance of materials joining, Important welding techniques, brazing, soldering and adhesive bonding.

Surface engineering: Importance of surface engineering, classification of surface engineering processes, introduction to thermal, thermo-chemical and electro-chemical surface engineering processes with their advantages, limitations and applications.

Learning Resources:

Text Books:

1. Kalpakjian and Schmid, Manufacturing Engineering and Technology, Prentice Hall, New Jersey, 2013.

2. Mikell P. Groover, Fundamentals of Modern Manufacturing, John Wiley & Sons, Inc, New Jersey, 2010.
3. R. S. Parmar, Welding processes and Technology, Khanna Publishers, 2010.
4. H.S.Bawa, Manufacturing Technology-I, Tata Mc Graw Hill Publishers New Delhi, 2007.

Reference Books:

1. DeGarmo, Black, and Kohser, Materials and Processes in Manufacturing, John Wiley & Sons, Inc, New York, 2011.
2. Serope Kalpakjian, Manufacturing processes for Engineering Materials, Addison Wesley, 2001.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc20_mm29/preview
2. https://archive.nptel.ac.in/noc/courses/noc17/SEM1/noc17-mm02/

SYLLABI

Minor: Materials Engineering

MM1M01 **3-0-0 (3)**

Structure and Properties of Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify materials based on their structure
CO-2	Correlate the structure with properties of materials
CO-3	Analyse the binary phase diagrams
CO-4	Appraise the importance of basic heat treatment processes

Syllabus:

Introduction: Historical perspective on materials, Classification of materials, Modern materials' needs, Materials tetrahedron, Bonding in solids - metallic bond, ionic bond, covalent bond.

Structure of solids: Crystal systems, Unit cells and space lattices, Coordination number, Metallic crystal structures, Atomic packing fraction for cubic and hexagonal close packed structures, Miller indices of planes and directions, Amorphous and polycrystalline materials. Ceramic crystal structures, Structure of polymers, Crystal imperfections – point defects, line defects, surface defects and volume defects.

Properties of materials: Physical properties, Thermal Properties, Electrical Properties, Magnetic Properties, Optical Properties, Mechanical properties, Structure-property correlations.

Constitution of alloys: Necessity of alloying, Substitutional and Interstitial solid solutions, Hume Rothery Rules, Intermediate phases.

Binary phase diagrams: Basic definitions, Gibbs phase rule, Construction of isomorphous phase diagram from cooling curves, Tie-line rule, Lever rule, Equilibrium heating and cooling of an isomorphous alloy, Eutectic, Eutectoid, Peritectic, Peritectoid, Monotectic and Syntectic reactions. Study of important binary systems of Fe-Fe_3C, Cu-Zn, Cu-Sn, Al-Cu and Al-Si, Introduction to strengthening mechanisms.

Basic heat treatment processes: Annealing, Normalising, Hardening and Tempering, Carburising, Nitriding, Influence of these processes on properties.

Learning Resources:

Text Books:

1. W.D. Callister, D.G. Rethwisch, Materials science and Engineering: An Introduction, Wiley, 2010, 8th ed.
2. S.H. Avener, Introduction to Physical Metallurgy, Tata McGraw-Hill Education, 2011, 2nd ed.
3. V. Raghavan, Materials Science & Engineering: A first course, PHI Learning, 2004, 5th ed.
4. R E. Hill and Abbaschain, Physical Metallurgy Principles, PWS Publishing Company, 2009, 4t ed.

Reference Books:

1. D S Clark and W. R. Varney, Physical Metallurgy for Engineers, CBS Publications, New Delhi, 1979, 1st ed.
2. R. E. Smallman, A.H.W. Ngan, Modern Physical Metallurgy, Butterworth-Heinemann Publications, 1999, 6th ed.,

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/108/112108150/
2. https://nptel.ac.in/courses/113/106/113106032/
3. https://nptel.ac.in/courses/113/102/113102080/

MM1M02 **3-0-0 (3)**

Engineering Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify materials based on structure and properties
CO-2	Describe structure, properties and applications of ferrous and non-ferrous alloys
CO-3	Differentiate metals/polymers/ceramics and their composites
CO-4	Suggest materials for a given engineering application

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-2	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-3	3	–	–	2	–	–	–	–	–	–	–	–	–	–	–	3
CO-4	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-5	3	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Historical perspective of engineering materials, importance of materials, materials for daily life, need for new materials development.

Metallic materials: ferrous alloys- carbon steels, low & high alloy steels, stainless steels, special steels: HSLA, marageing, HNS, light-weight steels, Fe-Si alloys, cast irons, non-ferrous alloys: aluminium, magnesium, titanium and nickel alloys.

Ceramics: typical structure of ceramics, glasses, silicate ceramics, carbon fibres, glasses.

Polymers: Polymerisation, thermosetting and thermoplastics, polymeric materials for special applications: high temperature, absorbing high energy impacts, limitations.

Composites: Classification based on matrix and dispersed phase, reinforced concrete, carbo-carbon composites, applications and limitations.

Learning Resources:

Text Books:

1. Smith, Structure and Properties of Engineering Alloys, McGraw-Hill Book Co., 1993, 2nd ed.
2. A. K. Bhargava, Engineering materials, PHI Learning Private Limited, 2013, 2nd ed.
3. Kennath Budinski, Michel K Budinski, Engineering Materials: Properties and Selection, Pearson Education India, 2009, 9th ed.
4. Witold Brostow, H E Hagg Lobland, Materials – Introduction & Applications, Wiley & Sons, 2017.
5. Donald R. Askeland, Pradeep P. Phule,, Science and Engineering of Materials, Thomson Learning, 2007, 5th ed.

6. Brian S. Mitchell, An Introduction to Materials Engineering and Science: for Chemical and Materials Engineers, John Wiley & Sons, Inc., 2004.
7. V. Raghavan, Materials Science and Engineering – A First Course, Prentice Hall of India Private Limited, 1999, 4th ed.

MM1M03 **3-0-0 (3)**

Characterization Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the principles of optical and electron microscopy.
CO-2	Analyse the X-ray diffraction data.
CO-3	Choose suitable characterization techniques for microstructural analysis of materials.
CO-4	Select suitable characterization techniques for compositional analysis of materials.
CO-5	Apply thermal analysis techniques for materials characterization.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-2	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-3	3	–	–	2	–	–	–	–	–	–	–	–	–	–	–	3
CO-4	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-5	3	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Microscopy: Working principle of microscope, optical microscope, concepts of magnification, resolution, numerical aperture, depth of field, principles of image formation, advantages, limitations and applications. Electron microscopy, SEM and TEM, electron source, electron-specimen interaction, mode of imaging, image contrast, SAD. Comparison of OM, SEM and TEM. Advantages, limitations and applications.

X-Ray diffraction: Properties of X-rays, X-Ray diffraction methods, applications of XRD.

Composition analysis techniques: EDS, WDX, XRF, XPS and AES, and EPMA.

Thermal analysis techniques: TGA, DSC, DTA and TMA.

Learning Resources:

Text Books:

1. S Zhang, L. Li and Ashok Kumar, Materials Characterization Techniques, CRC Press, 2008.
2. David B. Williams, C. Barry Carter, Transmission Electron Microscopy, Textbook for Materials Science, Springer, 2009, 2nd Edition.
3. Khangaonkar P R, Penram , An Introduction to Material Characterization, Intl. Publishing (India) Pvt. Ltd, Mumbai, 2010.
4. B.D.Cullity and S.R.Stock, Elements of X-Ray Diffraction, Prentice Hall, NJ, 2001, 3rd Edition.

Reference Books:

1. ASM Handbook, Vol.10, Materials Characterization, ASM International, USA, 1998.

2. Goldstein JI, Newbury DE, Michael JR, Ritchie NW, Scott JH, Joy DC, Scanning electron microscope (SEM) instrumentation: Scanning Electron Microscopy and X-Ray Microanalysis. Springer, New York, NY, 2018, 4th Edition.
3. J. W. Edington, Practical of Electron Microscope in material science: Electron Diffraction in the Electron Microscope- (Philips Technical Library) Macmillan Education UK (1975).

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc21_mm07/preview
2. https://youtu.be/KfQ4VNpWN4M
3. https://www.youtube.com/watch?v=UuHofNW40Yw
4. https://www.youtube.com/watch?v=Mr9-1Sz_CK0
5. https://www.youtube.com/watch?v=ArPXfPjOJQc
6. https://www.youtube.com/watch?v=07iZ7-IEyYE
7. https://www.youtube.com/watch?v=yguvwX_ia_A&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=2

MM1M04 **3-0-0 (3)**

Materials Degradation

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the thermodynamic and kinetic principles governing the material degradation in aqueous environment
CO-2	Desribe various forms of corrosion
CO-3	Explain corrosion mechanisms of materials in industry
CO-4	Predict the corrosion behaviour from corrosion data of material

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-2	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-3	3	–	–	2	–	–	–	–	–	–	–	–	–	–	–	3
CO-4	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-5	3	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Environmental degradation of a material: Definition and significance, overview of common material failures due to environmental degradation in industry, corrosion - basic definition and its cost.

Thermodynamics of metallic corrosion: EMF series and Nernst's law, EMF vs corrosion potential, Pourbaix diagram – construction, applications and examples, Effect of environmental variables on corrosion, passivity in metals and alloys.

Kinetic of corrosion, corrosion rate expressions, polarisation: Types, mixed potential theory, Evans diagram – construction and interpretation.

Forms of corrosion: Uniform, dealloying, intergranular, galvanic, crevice, pitting, environmentally induced cracking – types, erosion corrosion - cavitation, high temperature corrosion- oxidation-Ellingham diagrams, hot corrosion, microbially induced corrosion.

Corrosion testing procedures: Weight loss, spectroscopy and electrochemical methods, polarization methods – linear, cyclic and Tafel methods, electrochemical impedance spectroscopy, potentiostatic and galvanostatic techniques to study passivity.

Corrosion control, monitoring and prevention: change of environment, material design and optimisation - effect of metallurgical variables on corrosion, sorting of metallic materials based on their corrosion behaviour in various environments such as fresh water, marine and soil, anodic and cathodic protection, coatings, corrosion of non-metallic materials-composites, polymers and ceramics.

Learning Resources:

Text Books:

1. Denny A. Jones, Principles and Prevention of Corrosion, Prentice Hall, 1996, 2nd Edition.
2. Mars G. Fontana, Corrosion Engineering, McGraw-Hill Book Company, 1986, 3rd Edition.

Reference Books:

1. Fundamentals of Metallic Corrosion: Atmospheric and Media Corrosion of Metals, Philip A. Schweitzer, CRC Press, 2006, 2nd Edition.
2. An Introduction to Corrosion and Corrosion Engineering, H.H. Uhlig, R. Winston Revie, John Wiley & Sons, 2008, 4th Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/108/113108051/#
2. https://nptel.ac.in/courses/113/104/113104082/#

MM1M05 **3-0-0 (3)**

Materials Testing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe synthesis, properties, applications of nanomaterials
CO-2	Suggest advanced composite materials for innovative applications
CO-3	Discuss unique aspects of bulk metallic glasses and high entropy alloys
CO-4	Suggest appropriate biomaterials for desired biomedical applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-2	3	–	–	–	–	–	–	–	–	–	–	–	–	–	3	–
CO-3	3	–	–	2	–	–	–	–	–	–	–	–	–	–	–	3
CO-4	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
CO-5	3	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to advanced materials, classification.

Advanced Nanomaterials: Introduction, Classification of nanomaterials, Physical, chemical, mechanical properties of nanomaterials; applications. Preparation of nanomaterials by solid, liquid and vapour routes; Carbon nanotubes (CNTs), preparation, properties and applications, Graphene and other emerging 2-D nanomaterials.

Advanced Composites: General characteristics and classification of composites, Advanced metal matrix composites (AMMCs), advanced ceramic matrix composites (ACMCs), advanced polymer matrix composites (APMCs), hybrid composites; Types of reinforcements, interface bonding, toughening mechanism, Unique properties, Applications in structural and aerospace sectors, Nanocomposites.

Bulk metallic glasses (BMGs) and High entropy alloys (HEAs): Introduction to metallic glasses, Glass formation, essential properties and applications of BMGs, synthesis through solid and liquid routes. HEAs: Concept of thermodynamic stability, essential properties, applications and synthesis of HEAs.

Advanced Biomaterials: Overview of biomaterials, Biocompatibility; Advanced biometallics, bioceramics, biopolymers, applications; cardiovascular implants, orthopedic implants, ophthalmology biomaterials, dental materials, Nanobiomaterials for medical imaging.

Learning Resources:

Text Books:

1. Charles P. Poole Jr., Frank J. Owens, Introduction to Nanotechnology, Wiley India, New Delhi, 2010.
2. Krishan K. Chawla, Composite Materials, Springer, 2015, 3rd Ed.

3. C. Suryanarayana and A. Inoue, Bulk Metallic Glasses, CRC Press, 2017.
4. Bikramjit Basu, Biomaterials Science and Tissue Engineering: Principles and Methods, Cambridge Press, 2017.

Reference Books:

1. Carl C. Koch, Ilya A. Ovid'ko, Sudipta Seal, and Stan Veprek, Structural Nanocrystalline Materials: Fundamentals and Applications, Cambridge Press, 2007.
2. B. S. Murty et al., Textbook of Nanoscience and Nanotechnology, Universities Press, 2013.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/105/113105081/
2. https://nptel.ac.in/courses/113/105/113105057/

SYLLABI

Honors: Metallurgical and Materials Engineering

MM1H01 **3-0-0 (3)**

Diffusion in Solids

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the thermodynamic basis of crystal defects.
CO-2	Explain the laws governing the diffusion.
CO-3	Describe the mechanisms of diffusion.
CO-4	Suggest a method to measure diffusion rate.
CO-5	Analyse the role of diffusion in microstructure development.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	1		2	1	-	-	-	-	-	-	-	-	-	2	-	-
CO-2	1	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-
CO-3	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-
CO-4	1	1	1	1	-	-	-	-	-	-	-	-	-	1	-	-
CO-5	-	-	1	1	-	-	-	-	-	-	-	-	-	1	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Thermodynamics and defects in solids: Free energy, enthalpy and entropy Gibb's free energy. Thermodynamics and phase diagrams, Concept of the chemical potential and the activity of elements, Point defects: Equilibrium concentration of defects.

Fick's laws: Fick's laws of diffusion and thin film solution, Solution in semi- infinite diffusion couples (error function analysis), Solution for homogenization (separation of variables). Diffusion under chemical potential gradient, the composition profiles in an inter- diffusion zone and diffusion as a tool to make products: Diffusion under the thermodynamic driving forces, Driving force for diffusion and Fick's laws of diffusion, Product phase formations because of diffusion in real systems,.

Atomic mechanism of diffusion: Interstitial diffusion, Concept of random walk, Substitutional diffusion, Activation energy for diffusion, Orientation dependence Diffusion in the ordered phases.

Determination of different kinds of diffusion parameters: Matano-Boltzmann analysis, Calculation of diffusion parameters using the Matano-Boltzmann analysis, Den Broeder and Wagner's approach. Calculations of the integrated diffusion coefficients, Tracer diffusion coefficient and the vacancy wind effect, Recent developments on the Kirkendall effect, Physico-chemical approach, Grain boundary diffusion.

Phase diagram and diffusion in ternary and multicomponent systems: Ternary phase diagrams, Ternary and multicomponent diffusion, Intrinsic, integrated and the average diffusion coefficients.

Learning Resources:

Text Books:

1. Shewmon, Paul, Diffusion in Solids, Springer, 2016.

2. Helmut Mehrer, Diffusion in Solids: Fundamentals, Methods, Materials, Diffusion-Controlled Processes, Springer, 2009
3. Alok Paul, Tomi Laurila, Vesa Vuorinen, Sergiy V. Divinski, Thermodynamics, Diffusion and the Kirkendall Effect in Solids, Springer, 2014

Reference Books:

1. Philibert J., Atom movements, EDP Sciences, 2021
2. Porter DA, Easterling KE. Phase transformations in metals and alloys, CRC press, 2009.

Other Suggested Readings:

1. http://alexandria.tue.nl/extra2/200412361.pdf

MM26003 **3-0-0 (3)**

Ferrous Welding Metallurgy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the physical metallurgy of ferrous alloys.
CO-2	Discuss the factors that influence the microstructure and properties of weldments.
CO-3	Evaluate the impact of welding on the properties of ferrous alloys.
CO-4	Apply the principles of ferrous welding metallurgy to real-world problems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	1	1	2	2	-	-	-	-	-	-	-	-	-	1	-	-
CO-2	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO-3	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
CO-4	1	1	3	-	-	-	-	-	-	-	-	-	-	1	2	-
CO-5	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Ferrous Metallurgy: Classification, phase diagrams and their applications, microstructure of ferrous metals, solidification and cast structure, heat treatment and phase transformations, CCT diagrams, alloying elements effect on Fe-C phase diagrams

Weld microstructure: Welding metallurgy and weldability, zones of weldment, microstructural changes during welding, solidification and cooling rate effects on microstructure, grain growth and its impact on properties.

Effects of welding: The role of alloying elements. Heat flow, temperature distribution, and cooling rate and thermal cycle, Δt8/5. Thermal severity number. Impact of heat input, process, joint geometry, plate thickness, peak temperature and preheat. Weld dilution, Multi-pass welding microstructure.

Welding of steels: types of steels: plain carbon steels, alloy steels, tool steels. welding of automobile steels, structural steels, quenched and tempered steels, heat resistant steels, and cast irons. microstructure, pre and post weld preparation, common welding techniques, challenges and case studies. metallurgical defects and mitigation, cracking phenomena in ferrous materials, prevention and remedial techniques for cracking in ferrous alloy welds. classification, physical metallurgy of stainless steels, Schaeffler's diagram, welding fillers, techniques for stainless steel welding.

Weld Properties: Tensile, compressive, and bending properties, fatigue and fracture mechanics, corrosion behavior of welded ferrous metals

Case Studies and Practical Examples: Case studies of real-life welding projects, practical examples of welding processes and procedures

Learning Resources:

Text Books:

1. J.G. Lippold and D.J. Kotecki, "Metallurgy and Welding for Engineers", 2nd edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2005.
2. J.C. Lippold and D.J. Kotecki, "Welding Metallurgy and Weldability of Stainless Steels", John Wiley & Sons, Inc., Hoboken, New Jersey, 2005.
3. Sindo Kou, "Welding Metallurgy", 2nd edition, John Wiley & Sons, Inc., Hoboken, New Jersey, 2003.
4. J.F. Lancaster, "Practical Welding Metallurgy", 2nd edition, Woodhead Publishing Limited, Cambridge, England, 2005.

Reference Books:

1. Metals Handbook Desk Edition, American Society for Metals, USA, 1998.
2. Welding handbook, American Welding Society, 8th edition, vol.5, USA, 2011.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc23_me49/preview

MM16022 **3-0-0 (3)**

Additive Manufacturing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the basic concepts and importance of additive manufacturing
CO-2	Describe the principles, processes and advantages of additive manufacturing systems
CO-3	Apply the knowledge of additive manufacturing for various real-life applications
CO-4	Suggest mitigation techniques for additive manufacturing defects
CO-5	Discuss importance and future applications of additive manufacturing field

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	-	-	1	-	2	-	-	-	-	-	-	-	1	-	-	-
CO-2	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-
CO-3	-	-	1	-	1	-	-	-	-	-	-	-	1	-	2	-
CO-4	2	-	1	-	2	-	-	-	-	-	-	-	-	-	1	-
CO-5	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview, basic principles and advantages of additive manufacturing, procedure of product development in additive manufacturing, classification of additive manufacturing processes.

Generic AM process: CAD, conversion of STL, transfer to AM machine and STL file manipulation, machine setup, build, removal, distinction between AM and CNC machining, reverse engineering

Additive Manufacturing Processes: Z-Corporation 3D-printing, Stereolithography apparatus (SLA), Fused deposition modeling (FDM), Laminated Object Manufacturing (LOM), Selective deposition lamination (SDL), Ultrasonic consolidation, Material Jetting, Binder jetting

Powder bed fusion processes: Selective laser sintering (SLS), Laser engineered net shaping (LENS), Selective laser melting (SLM), Electron beam melting (EBM), materials, powder fusion mechanisms, powder handling challenges, powder recycling, defects

Direct energy deposition processes: DED process description, powder feeding, wire feeding, laser and electron-based deposition processes

Post-Processing in Additive Manufacturing: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques, applications of additive manufacturing in rapid prototyping, rapid manufacturing, rapid tooling, repairing and coating.

Future scope in Additive Manufacturing: Scope of AM in various fields, importance and applications.

Learning Resources:

Text Books:

1. C.K. Chua, K.F. Leong, C.S. Lim: Rapid prototyping- Principles and applications, 3rd Ed., World Scientific Publishers, 2010.
2. Gibson, I, Rosen D W., and Stucker B., Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010
3. Chee Kai Chua, Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications: Fourth Edition of Rapid Prototyping, World Scientific Publishers, 2014
4. A. Gebhardt: Rapid prototyping, Hanser Gardener Publications, 2003.

Reference Books:

1. Additive Manufacturing Processes, Editor: David L. Bourell, William Frazier, Howard Kuhn, and Mohsen Seifi, ASM Hand Book, Volume 24, ASM International 2020.

Other Suggested Readings:

1. https://additivemanufacturing.com/basics/
2. https://www.additivemanufacturing.media/.

MM16042 **3-0-0 (3)**

Aerospace Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Outline the material selection criteria for aerospace applications
CO-2	Identify components and materials in aeroplanes and space vehicles
CO-3	Provide solutions for materials selection, processing, testing and performance evaluation.
CO-4	Discuss the creep, fatigue and high-temperature degradation phenomena with respect to aerospace and gas turbine engine components
CO-5	Suggest advanced materials for the aerospace applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	1	-	-	-	-	-	-	-	-	-	-	-	2	-	3	1
CO-2	1	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-
CO-3	1	3	2	2	-	-	-	-	-	-	-	-	1	-	2	-
CO-4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
CO-5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Requirements of space and aerospace materials, land base and aerospace materials, identification of components of airplanes and space vehicles, materials usage in each section and criticality of the components and their materials selection, gas turbine, and aero engines; creep, fatigue and corrosion; Nickel and Cobalt based super alloys, special steels, aluminum alloys, titanium alloys, intermetallic, ceramics and their composites, Carbon-Carbon composites, new high strength and advanced materials in aerospace structural components.

Learning Resources:

Text Books:

1. Aerospace Materials and Material Technologies-Aerospace Materials (Vol. 1) and Aerospace Material Technologies (Vol. 2), N. Eswara Prasad, R.J.H. Wanhill, Indian Institute of Metals Series, Springer, 2017.
2. Materials Selection in Mechanical Design, Michael F. Ashby, Butterworth-Heinemann, 2005
3. Aircraft Materials and Processes, George F. Titterton, Himalayan Books, New Delhi, 1998.

Reference Books:

1. Manufacturing Technology for Aerospace Structural Materials, F. C. Campbell, Elsevier, UK, 2006
2. Aerospace Materials with Materials Technology for Engineers, Vol. 1-4, Balram Gupta, S. Chand & Co., New Delhi, 1996 and 2002.

Other Suggested Readings:

1. Light Alloys: From Traditional Alloys to Nanocrystals, Polmear, I. J., Elsevier, 2005, 4th ed.
2. The Superalloys: Fundamentals and Applications, Reed, R. C., Cambridge Univ. Press, 2006.
3. Aerospace Materials, Cantor, B., Assender, H., and Grant, P. (Eds.), CRC Press, 2001

MM1H05 **3-0-0 (3)**

Advanced Ceramics for Strategic Applications

Pre-Requisites: **None**

Course Outcomes:

CO-1	Illustrate ceramic processing and fabrication techniques
CO-2	Identify various types of ceramic materials and properties
CO-3	Develop structure-processing-property relationship of ceramics
CO-4	Formulate ceramics for strategic applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	1	-	-	-	-	-	-	-	-	-	-	-	1	-	3	-
CO-2	1	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-
CO-3	1	-	2	-	-	-	-	-	-	-	-	-	-	2	1	-
CO-4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Oxide and non-oxide ceramics, their chemical formulae, crystal and defect structures, nonstoichiometry and typical properties.

Powder Preparation: Physical methods, chemical routes - coprecipitation, sol-gel, hydrothermal, combustion synthesis, high temperature reaction (solid state reaction).

Basic principles and techniques of consolidation and shaping of ceramics: powder pressing- uniaxial, biaxial and cold isostatic and hot isostatic, injection moulding, slip casting, calendaring, multilayering.

Mechanical behaviour: Fracture mechanics and tribology; Electrical behaviour: insulating (dielectric, ferroelectric, piezoelectric, pyroelectric) semiconducting, conducting, superconducting and ionically conducting, specific materials and their applications; Magnetic behaviour: basic principles, materials and their applications.

Engineering applications: at room and high temperatures (including armour application) and; Bio- medical applications.

Transparent ceramics, coatings and films: preparation and applications; Porous ceramics and ceramic membrane: fabrication techniques and applications in separation technology.

Ceramics for energy and environment technologies: Fuel cell, lithium battery, gas sensor and catalytic support.

Ceramics matrix composites: Types, Preparation and properties (including nano- composites)

Exotic ceramics: functionally graded, smart/ Intelligent, bio-mimetic and nano - ceramics.

Learning Resources:

Text Books:

1. Fundamental of Ceramics by Michel W. Barsoum, McGraw Hill International edition, 1997.
2. Modern Ceramic Engineering by David. W. Richerson, Mercel Dekker, NY 1992.
3. Ceramic Processing and Sintering by M. N. Rahman, Mercel Dekker, 2003.

Reference Books:

1. Handbook of Advanced Ceramics, Parts 1 and 2, S. Somiya, Academic Press, 2006.

Other Suggested Readings:

1. NPTEL Link: https://nptel.ac.in/courses/113/105/113105015/.