CURRICULUM & SYLLABI

Integrated M. Tech. WELDING TECHNOLOGY AND NON-DESTRUCTIVE TESTING

Dual Degree (Bachelor and Master of Technology) in Metallurgical and Materials Engineering

Effective from AY: 2025-26



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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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: Integrated M. Tech. Welding Technology and Non-destructive Testing

Program Educational Objectives

PEO-1	Apply core and advanced metallurgical and materials engineering knowledge for the development of materials through extraction, refining, processing and manufacturing to fulfil industrial and societal needs.
PEO-2	Formulate innovative inspection solutions, model, design, process, characterize and evaluate material systems for generic, industrial and strategic applications.
PEO-3	Practice industrial standards, safety measures and work effectively as an individual or in a team in inter- and multi-disciplinary projects with ethics and professionalism.
PEO-4	Pursue life-long learning by enhancing knowledge and 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	2	2
Keep abreast with rapid strides of technology and improve academic standards through innovative teaching and learning processes.	3	3	2	3
Engage in quality research in metallurgical, materials and allied engineering areas.	3	3	3	2
Develop linkages with leading academic, research, and industrial organizations for societal benefit.	2	2	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: Integrated M. Tech. Welding Technology and Non-destructive Testing

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, mechanical and welding 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 and present professional and technical reports efficiently

CURRICULUM

Integrated M. Tech. Welding Technology and Non-destructive Testing

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	Introduction to Materials Science and Engineering	3-0-0	3
4	MM1101	Design Thinking	0-1-4	3
5	ME1161	Engineering Graphics	1-0-4	3
6	ME1165	Engineering Workshop Practice	0-1-2	2
7	IC1101	Extra Academic Activity - I	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	Extra Academic Activity - II	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	MM1213	Electronic and Magnetic Materials	3-0-0	3
6	MM1209	Physical Metallurgy and Metallography Laboratory	0-1-2	2
7	MM1211	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	MM1208	Casting and Solidification Processing	3-0-0	3
5	MM1210	Ceramics and Composites Technology	3-0-0	3
6	MM1212	Phase Transformations and Heat Treatment Laboratory	0-1-2	2
7	MM1214	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	MM26001	Welding Processes	3-0-0	3
2	MM26003	Ferrous Welding Metallurgy	2-1-0	3
3	MM26005	Non-destructive Testing Techniques	3-0-0	3
4		Professional Elective- IV	3-0-0	3
5		Professional Elective- V	3-0-0	3
6	MM26007	Welding Processes Laboratory	0-1-2	2
7	MM26009	Non-destructive Testing Laboratory	0-1-2	2
			Total Credits	**19**

8th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM26002	Non-ferrous Welding Metallurgy	3-0-2	4
2	MM26004	Advanced Nondestructive Testing Techniques	3-0-0	3
3		Professional Elective- VI	3-0-0	3
4		Professional Elective- VII	3-0-0	3
5		Professional Elective- VIII	3-0-0	3
6	MM26006	Advanced Experimental Techniques Laboratory	0-1-2	2
7	MM16008	Mechanical Behavior of Materials Laboratory	0-1-2	2
8	MM26096	Minor Project	0-0-0	2
			Total Credits	**22**

9th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM26089	Seminar and Technical Writing	0-0-0	2
2	MM26093	Comprehensive Viva-Voce	0-0-0	2
3	MM26097	Dissertation: Part-A	0-0-0	8
4	MM26091	Summer Internship/ Research Experience	0-0-0	2
			Total Credits	14

10th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MM26098	Dissertation: Part-B	0-0-0	12
			Total Credits	12

Total credits:121+67 = 188

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	MM26021	Design of Weldments
2	MM26023	Joining and NDT of Ceramics, Polymers and Composites
3	MM26025	Corrosion of Weldments
4	MM26027	Advanced Experimental Techniques
5	MM26029	Fatigue and Fracture Mechanics
6	MM16041	Strengthening Mechanisms

Professional Elective-VI, VII, VIII		
S.No.	**Code**	**Course Title**
1	MM26022	Residual Stresses and Distortion
2	MM26024	Welding Application Technology
3	MM26026	Statistics, Quality and Reliability
4	MM26028	Mechanical Behavior of Weldments
5	MM26030	Computational Methods for Welding and Joining
6	MM30003	Additive Manufacturing Technologies
7	MM36012	Surface Engineering and coating 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 Graphics	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	126
Professional Elective	24
Total Graded Credit Requirement	188

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 **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.

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

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

Engineering Graphics

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	Analyse the details of an object through development of surfaces and intersection of surfaces
CO6	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	-	-	-	-	-	-
CO6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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)**

Fundamentals of AutoCAD:

Introduction to Auto-CAD, DRAW tools, MODIFY tools, TEXT, DIMENSION, PROPERTIES **(AutoCAD)**

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 & AutoCAD)**

Projections of Planes:

Projections of a plane perpendicular to one of the reference planes and inclined to the other, Oblique planes. **(Conventional & 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. **(Conventional & AutoCAD).**

Section of Solids:

Sectional planes, Sectional views - Prism, pyramid, cylinder and cone, true shape of the section. **(Conventional & AutoCAD).**

Learning Resources:

Text Books:

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

Reference Books:

1. Basant Agrawal, C M Agrawal, Engineering Drawing, Third edition, McGraw Hill Education, 2019.
2. Prof. Sham Tickoo, AutoCAD 2017 for Engineers & Designers, 23ed, Basic and Intermediate, Dreamtech Press, 2016.

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).

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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: MM1101

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/

MM1213 **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/

MM1209 **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

MM1211 **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: MM1101, 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

MM1208 **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.

MM1210 **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

MM1212 **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

MM26001 **3-0-0 (3)**

Welding Processes

Pre-Requisites: **None**

Course Outcomes:

CO-1	Compare the working principles of traditional and modern welding processes
CO-2	Relate welding process parameters with weld quality.
CO-3	Identify various welding defects and remedial measures
CO-4	Select a suitable welding process for a given 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	-	-	1	–	–	–	–	–	–	–	3	3	–	–	–
CO-2	3	-	-	1	–	–	–	–	–	–	–	–	–	3	–	–
CO-3	3	2	1	1	–	–	–	–	–	–	–	–	–	3	–	–
CO-4	3	-	-	1	–	–	–	–	–	–	–	3	–	3	–	1

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

Syllabus:

Fundamentals of welding: soldering and brazing, classification of welding processes, types of weld joints, welding positions, welding arc characteristics, arc initiation, power source characteristics.

Manual metal arc welding: principles of operation, electrode designation, types of electrodes, and their applications, Gas tungsten arc welding (GTAW): polarities in GTAW, tungsten electrodes, shielding gases, filler wire, applications, variations in GTAW (pulsed and hot wire), plasma arc welding (PAW): modes of PAW (Micro- mode, low current melt-in mode, and key- hole mode), applications, gas metal arc welding (GMAW): modes of metal transfer (Spray, globular, short-circuit and pulsed spray), self-regulating arc, applications. Fluxed core arc welding (FCAW): variants in FCAW (self-shielded and gas shielded), types of electrodes, applications, submerged arc welding (SAW): classification of flux and electrodes in SAW, applications.

Gas welding processes: fuel gases, oxy acetylene welding, types of flames, applications, other welding processes: resistance welding (RW): principles of operation, types of RW, spot welding, resistance spot welding cycle, seam welding, projection, flash butt and percussion.

Electron beam welding (EBW): Laser beam welding (LBW): physics of lasers, types of lasers, operation of laser welding setup, advantages and limitations, applications.

Solid-state welding: need for solid-state welding, types of solid-state welding, Friction welding: variations, steps in friction welding, types and applications. Friction stir welding: principles of operation, metal flow phenomena, tools, process variables and applications, explosive, diffusion and ultrasonic welding, principles of operation, process characteristics and applications.

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

Text Books:

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, Vol. 6, 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://www.twi-global.com/technical-knowledge/faqs/what-is-welding
2. https://nptel.ac.in/courses/113/106/113106087/

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: MM203

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

MM1330 **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/

MM26021 **3-0-0 (3)**

Design of Weldments

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss welding symbols and their use.
CO-2	Analyze weldments for residual stress and its effects on the weldment performance.
CO-3	Evaluate weldment strength and reliability using design factors and stress analysis methods.
CO-4	Design durable weldments to sustain industrial service conditions.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

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

Syllabus:

Introduction to Welding Symbols: Types of welding symbols, reading and interpreting welding symbols, symbol conventions and standards

Weld Residual Stress: Causes and effects of residual stress, measurement techniques for residual stress, mitigation techniques for residual stress

Stresses in weld joints and design: Stresses in butt and fillet joints, normal / shear stress, static, elevated temp strengths, impact behaviour, types of failure, structural details standards and specifications. construction of boilers, pressure vessels, pipelines, etc.

Weld Strength Calculations: Basic concepts of weld strength, design factors affecting weld strength, calculation methods for weld strength

Stress Analysis of Welds: Types of weld stress, stress analysis methods, fatigue life calculations

Weld Design for Fatigue: SN curve, fatigue failure modes in welds, fatigue strength of welded joints, design considerations for fatigue resistance, effect of residual stresses, fatigue resistance improvement.

Applications and Case Studies: Industrial applications, case studies of weldment design, emerging trends in weldment design, future directions in weldment design

Learning Resources:

Text Books:

1. "Welding Symbols Quick Card" by Builder's Book, Inc. (2011)
2. "Residual Stress, Thermomechanics & Infrared Imaging, Hybrid Techniques and Inverse Problems, Volume 9: Proceedings of the 2015 Annual Conference on Experimental and Applied Mechanics" edited by Helena Jin and K. Elliott Cramer (2015)
3. "Welding Design and Fabrication" by K. Mangala Sunder (2015)
4. Welding Symbols on Drawings by E.N. Gregory and A.A. Armstrong, 6th Edition, Woodhead Publishing Limited, 2013.
5. Welding Residual Stress and Its Effects on Fatigue and Fracture edited by Y. Murakami and R. O. Ritchie, 1st Edition, Elsevier Science, 1998.
6. Design of Welded Structures by O. K. Chopra and S. J. Lee, 1st Edition, John Wiley & Sons, 2001.
7. Stress Analysis of Welded Structures by K. F. Chung, 2nd Edition, CRC Press, 2019.

Reference Books:

1. "Structural Welding Code - Steel: Ansi/Aws D1.1-2010" by American Welding Society (2010)
2. "Fatigue Design of Welded Joints and Components: Recommendations of IIW Joint Working Group XIII–XV" edited by M. Gurney and J. Fricke (2016)
3. Welding Metallurgy and Weldability of Stainless Steels by J. C. Lippold and D. J. Kotecki, 1st Edition, John Wiley & Sons, 2005.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc23_me49/preview.

MM26023 **3-0-0 (3)**

Joining and NDT of Ceramics, Polymers and Composites

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the characteristics of ceramics, polymers and composites.
CO-2	Identify materials and methods for ceramics, polymers and composites joining.
CO-3	Distinguish NDT methods for metals, ceramics, polymers and composites.
CO-4	Demonstrate advanced joining and NDT techniques for polymers, ceramics and composites.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

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

Syllabus:

Introduction to Materials: Ceramics, polymers and composites - Introduction, classification, properties, applications.

Introduction to Joining techniques: Necessity for materials (Ceramics, polymers and composites) joining, conventional and non-conventional joining methods for different materials (similar or dissimilar materials joining), its advantages and limitations.

Joining of ceramics: Ceramic-metal/ceramic joining technologies (brazing, metallizing, diffusion bonding etc.); ceramic-polymer joining technologies (adhesive, chemical, brazing etc.), advanced joining techniques (transient liquid phase), active solders, challenges in all these joining processes.

Joining of polymers: Joining methods for polymers – Welding (thermal, mechanical and electromagnetic methods), adhesive bonding (epoxy resins, acrylic acid diesters, cyanoacrylates), riveting, thread systems, press and snap fits etc.

Joining of composites: Different joining techniques of composites (sintering, welding, brazing, soldering), adhesion - cementitious joining, joining using organic and inorganic binders, joining using carbon binders, fastening etc.

Non-destructive Techniques for ceramics: Processing of ceramics: sol gel, co-precipitation, solvent vaporization, porous ceramics, and defects in ceramics. Visual inspection, Ultrasonic NDT, Radiography, Eddy Current, Magnetic Particle NDT, Acoustic Emission NDT, Dye Penetrant NDT, Leak Testing, X-ray tomography, Process compensated resonance testing.

Non-destructive Techniques for composites: Fabrication of composites- Hand layout method, Injection

molding, compression molding, resin transfer, pultrution, etc., fracture behaviour of composites, Manufacturing defects and process defects in composites, Modes of failure in composites. Visual testing, Tap test, Ultrasonic testing, Radiography, Shearography testing, Acoustography, Acoustic Emission NDT, Thermography.

Learning Resources:

Text Books:

4. W. Bolton, Engineering Materials Technology, Butterworth-Heinemann, 2001, 3rd edition.
5. Shigeyuki Somiya, Advance Technical Ceramics, Elsevier, 2003.
6. Deborah D. L. Chung, Composite Materials: Science and Applications, Springer, 210, 2nd Edition.
7. B. Raymond, Seymour and Charles E. Carraher Jr., Marcel Dekkar, Polymer Chemistry, An Introduction, Inc., 1987, 2nd Edition.
8. Sindo Kou, Welding Metallurgy, John Wiley & Sons, 2nd Edition, 2002.
9. Vistap M. Karbhari, Non-Destructive Evaluation (NDE) of Polymer Matrix Composites, Woodhead Publishing, 2013, 1st edition.

Reference Books:

3. S. Somiya, Handbook of Advanced Ceramics, Parts 1 and 2, Academic Press, 2006.
4. Welding Handbook, Vol 2- Welding Processes, AWS, 2004, 9th Edition.
5. Advances in joining of Ceramics, The American Ceramic Society, Wiley Publishers, 2002.
6. William Andrew, Handbook of plastics joining: a practical guide, Inc., 2008, 2nd Edition.
7. K. K. Chawla, Composite Material: Science and Engineering, Springer, 2012 and 3rd edition.
8. David W Richerson, Modern Ceramic Engineering, 2nd edition.

Other Suggested Readings:

3. https://nptel.ac.in/content/storage2/courses/101104010/downloads/Lecture4.pdf
4. https://www.youtube.com/watch?v=7Be7hGvqoAg
5. https://www.twi-global.com/technical-knowledge/faqs/what-is-welding
6. https://www.youtube.com/watch?v=ZMJ7O4vs-Q8

MM26025 **3-0-0 (3)**

Corrosion of Weldments

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the principles of corrosion and corrosion mechanisms.
CO-2	Evaluate the corrosion behaviour of Ferrous and Non-Ferrous Weldments.
CO-3	Explain the corrosion of dissimilar metal weldments and weld corrosion case studies.
CO-4	Suggest suitable techniques for monitoring and testing of weldments.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

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

Syllabus:

Principles of Corrosion: Introduction, Corrosion rate expressions, Galvanic and Electrochemical Series, Nernst Expression, Electrochemical aspects- Electrochemical reactions, polarization, passivity, Forms of Corrosion, Preferential HAZ Corrosion, Preferential Weld Metal Corrosion, Mitigation of Preferential Weldment Corrosion, Stress corrosion cracking.

Corrosion of Weldments: Factors influencing and different forms of weld corrosion, Weld Corrosion of Carbon- and Low-Carbon Steel Weldments, Austenitic-, Ferritic-, Martensitic-, Duplex- Stainless Steel Weldments, Non-Ferrous Alloy Weldments, Dissimilar Metal Weldments, Corrosion-Resistant Alloys. Corrosion Monitoring and Testing- Effect of Welding Practice on Weldment Corrosion, Direct testing of coupons, Electrochemical techniques, Testing methods for corrosion of weldments.

Learning Resources:

Text Books:

1. J R Davis (ed), Corrosion of Weldments, ASM International, 2006.
2. M G Fontana, N D Greene, Corrosion Engineering, McGraw Hill, New York, 1967.
3. Nestor Perez, Electrochemistry and Corrosion Science, Kluwer, 2004.

Reference Books:

1. ASM Metal Handbook, Vol 13A- Corrosion, 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, IIT Kanpur).

MM26027 **3-0-0 (3)**

Advanced Experimental Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Demonstrate the principles and operation of different microscopes
CO-2	Analyze images of optical and electron microscopes
CO-3	Use suitable specimen preparation technique for a particular characterization method
CO-4	Explain the operation of dilatometers and interferometers for the characterization of materials
CO-5	Distinguish suitable thermal analysis techniques for different purposes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

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

Syllabus:

Introduction: Stereomicroscopy and its applications, Basic introduction about transmission electron microscope (TEM): Comparison with optical microscope and X-ray diffraction, Properties of electrons, electron beam-specimen interaction.

Design of electron microscope: signal detectors, electron lenses, resolving power, image formation, arrangement for microscopy and diffraction. Specimen preparation and image interpretation: case studies. Field Emission Microscope. Scanning electron microscope (SEM), principles of microprobe analysis. principles of microprobe analysis, Introduction to EBSD.

Thermal analysis of phase transformations: ordinary thermal method, inverse rate curves, differential thermal analysis, derived differential thermal analysis, thermal analysis at high temperatures, thermal analysis with rapid heating and cooling. Thermogravimetric analysis: TG design and experimental concerns. Cahn microbalance operation. Simultaneous thermal analysis. Dilatometry: Single push rod dilatometer, dual push rod dilatometer, calibration. Interferometry: Principles, Michelson interferometer, dilatometric interferometer. Growth of single crystals by zone melting.

Learning Resources:

Text Books:

1. Yang Leng, Materials Characterization Introduction to Microscopic and Spectroscopic Methods, JohnWiley & Sons (Asia) Pte Ltd, 2008
2. C. Suryanarayana and M. Grant Norton, X-Ray Diffraction A Practical Approach, Springer

Science+Business Media, LLC, 1998

Reference Books:

1. ASM Handbook: Materials Characterization, ASM International, 2008.
2. V. T. Cherapin and A. K. Mallik: Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.

Other Suggested Readings:

1. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.
2. S.J.B. Reed: Electron Microprobe Analysis, Cambridge University Press, London, 1975.

MM26029 **3-0-0 (3)**

Fatigue and Fracture Mechanics

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:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	-	2	-	1
CO-3	3	-	-	2	-	1
CO-4	3	-	-	2	-	1

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

Syllabus:

Concepts: Stress, Strain, Analysis of stresses and strains, principal stresses and strains. Stress / Strain Invariants 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

Concept of fracture: Steps of fracture, Classification of fracture, Strain energy release rate, Stress intensity factor, Determination of fracture toughness, KIc Fracture toughness, Mechanism of ductile and brittle fracture, Modes of fracture, Common causes of engineering fracture, Fractography, Microscopic fracture modes, Fractographic observation of cleavage/brittle, quasi-cleavage and ductile/dimple fracture

Plasticity: Plasticity at the crack tip, Orowan correction, Strain energy release rate, Irwin's modification, plastic zone shape and size, effect of constraint, plane stress, plane strain, thickness, CTOD, J integral

Fatigue testing and its significance: Stress cycles, S-N curve, HCF, LCF, R ratio, Goodman diagram, Paris law, fatigue limit, mechanism of fatigue failure, effect of stress concentration, size, surface condition and environments on fatigue, effect of metallurgical variables on fatigue properties.

Time-dependent deformation: Creep, different stages of creep, creep and stress rupture, creep mechanisms.

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

Case studies: Failure analysis of welds, Recommendations for Considering Welding Residual Stresses,

prevention of failures.

Learning Resources:

Text Books:

1. Mechanical Behavior of Materials, M.A. Meyers
2. and K.K. Chawla, Prentice Hall Inc., 1999.
3. Fracture Mechanics- Fundamentals and Applications, T. L. Anderson, 3rd Edition, CRC Press, 2011.
4. Mechanical Metallurgy, G. E. Dieter, 3rd Edition, McGraw-Hill, 2013.

Reference Books:

1. Deformation and Fracture Mechanics of Engineering Materials, R. W. Hertzberg, 4th Edition, John Wiley & Sons Inc., 2012.
2. Fundamentals of Creep in Metals and Alloys, Michael Kassner, 2nd Edition, Elsevier Science, 2009.
3. Fatigue and Fracture Testing of Weldments, McHencry and Potter (Editors), ASTM STP 1058, Philadelphia, PA, 19103.

MM16041 **3-0-0 (3)**

Strengthening Mechanisms

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify strengthening mechanisms in steels and advanced materials
CO-2	Explain the mechanisms of strengthening in metals and alloys
CO-3	Design thermo-mechanical treatments for high strength steels and alloys
CO-4	Design new materials/heat treatments based on strengthening mechanisms

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	-	3	2	1	
CO-2	-	-	3	2	1	
CO-3	-	-	3	2	1	
CO-4	-	-	3	2	1	

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

Syllabus:

Different methods of strengthening solids; Thermal activation processes; Theories and mechanisms of strain hardening; Solid solution strengthening and Order-disorder transformations; Precipitation hardening; Theories of strengthening and over ageing; Dispersion hardening and theories; Martensitic and bainitic transformations; Special thermo-mechanical treatments for steels; Grain refinement; super plasticity; Fibre-strengthening

Learning Resources:

Text Books:

1. B. Geddes, H. Leon and X. Huang, Strengthening mechanisms, ASM International
2. D. K. Felbeck, Introduction to Strengthening mechanisms, Prentice Hall, London, 1968; Publishedonline by Cambridge University Press: 04 July 2016.
3. D. Hull and D.J. Bacon, Introduction to Dislocations, Butterworth Heinemann, 1984,5th edition.

Reference Books:

1. William D. Callister, Materials Science and Engineering – An introduction, Jr, John Wiley & Sons,Inc. 2004, sixth edition.
2. C.A. Wert and R. M. Thomson, Physics of solids, McGraw-Hill Publishers, 1964

Other Suggested Readings:

1. https://nptel.ac.in/courses/112108150 MIT Open Course Ware, etc.

2. https://www.ias.ac.in/public/Volumes/sadh/003/04/0275-0296.pdf

MM26022 **3-0-0 (3)**

Residual Stresses and Distortion

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the importance of residual stress and distortion control in weldments.
CO-2	Analyze the causes for residual stress and distortion in weld fabrication.
CO-3	Discuss techniques to quantify residual stresses and distortion in welded parts.
CO-4	Recommend methods to reduce the residual stresses and distortion.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	2	-	-	-
CO-2	3	1	2	-	-	-
CO-3	3	3	2	1	-	2
CO-4	3	-	2	1	-	-

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

Syllabus:

Significance of Structural and Residual Stress Analysis, Nature and Causes of Residual Stress, Origin of Thermal Stresses. Residual Stresses due to Mismatch, Residual Stresses from Nonuniform and Nonelastic Strains. Residual Stresses and Distortion caused by Manufacturing Processes: Casting, Welding and Joining, Powder Metal processing, Thermal Forming, Cutting, Gear manufacture, Residual Stress Formation and Distortion in rail steels, Causes of Distortion in Weldments. Residual Stress During Hardening Processes. Residual Stresses in Carburized, Carbonitrided, and Case-Hardened Components, Residual Stresses in Nitriding, Induction Hardening, Hardening by Reheating and Quenching, Metallo-Thermo-Mechanics–Application to Quenching, Effects of Cryogenic Cooling on Residual Stresses, Structure and Substructure. Measurement of Residual Stresses: The X-ray Diffraction Technique, Synchrotron X-ray Diffraction, Neutron Diffraction, Ultrasonics, A Sectioning Technique Using Electric-Resistance Strain Gauges, The Mathar-Soete Hole Drilling Technique, The Rosenthal-Norton Section Technique, The Gunnert Drilling Technique. Residual Stress Distribution Patterns, Effects of specimen size and Weight, Effects of welding sequence, Residual stress in welds made with different welding processes, Effects of residual stresses and distortions on structural strength, fatigue and unstable fracture. Residual Stress and Distortion Control, The Interplay Between Residual Stresses and Distortion, Prevention Versus Remediation, manipulation of residual stresses and distortion, Stress-Relaxation Techniques, Post heat treatment after welding. Calculation/ prediction of residual stress using modern tools, case studies.

Learning Resources:

Text Books:

1. Welding Metallurgy, Sindo Kou, A John Wiley & sons, inc., publication Second Edition (2002)
2. AWS Welding Handbook, VOL-1 - 9th Ed (2001)- Welding Science and Technology

3. Principles of Welding_ Processes, Physics, Chemistry, and Metallurgy, Robert W. Messler Jr - (2004, Wiley-VCH)
4. Practical Residual Stress Measurement Methods, Ed. by Gary S. Schajer, A John Wiley & sons, inc., publication 2013
5. Handbook of Residual Stress and Deformation of Steel, Ed. by G. Totten, M. Howes, T. Inoue, ASM International, 2002

Reference Books:

1. The use of a portable X-ray unit for measuring residual stresses in aluminum, titanium, and steel alloys. In Advances in X-ray analysis. D. A. Boldstad and W. E. Quist, eds. New York: Plenum Press. 1965.
2. Welding Deformation and Residual Stress Prevention, Y. Ueda, H. Murakawa, N. Ma, Elsevier, 2012
3. Structural and Residual Stress Analysis by Non-destructive Methods Evaluation Application and Assessment, V. Hauk, Elsevier, 1997
4. Computational Welding Mechanics, J. A. Goldak and A. Mehdi, Springer, NY, 2005.

MM26024 **3-0-0 (3)**

Welding Application Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Evaluate the impact of welding procedures and specifications on weld quality.
CO-2	Develop and implement welding fabrication plans.
CO-3	Apply confirming documentation for weld inspection.
CO-4	Apply preventive and corrective measures for welding defects and distortions.
CO-5	Demonstrate knowledge of relevant standards and codes for weld fabrication.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	1
CO-2	3	-	2	2	-	1
CO-3	3	-	2	2	-	1
CO-4	3	-	-	2	-	1
CO-5	3	-	-	2	-	3

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

Syllabus:

Introduction to Quality Control of Welding Construction: Importance of Quality Control in Welding Fabrication, Global Trends in Quality Management Systems (QC and QA), Design Quality and Manufacturing Quality

Welding Codes and Standards: Overview of Welding Codes and Standards, AWS D1.1 and ISO 3834 standards, Welding Procedure Specifications (WPS) and Welding Qualification

Welding Fabrication Planning: Drafting and Qualification of Welding Procedure Specification (WPS), Estimation of Welding Work Volume, Planning of Schedule, Welding Equipment, Welding Personnel, Testing and Inspection and

Welding Costs: Materials, equipment, personal cost consideration.

Heat Treatment Before and After Welding: Introduction to Heat Treatment, Pre-Welding Heat Treatment, Post Welding Heat Treatment, Heat Treatment Methods, Heat Treatment Standards and Codes

Prevention and Correction of Weld Distortion: Introduction to Weld Distortion, Causes of Weld Distortion, Prevention of Weld Distortion, Correction Methods of Weld Distortion

Welding Performance Control: Introduction to Welding Performance Control, Types of Welding Performance Control, Welding Process Variables and their Effect on Welding Performance, Monitoring and Controlling Welding Performance, Testing and Inspection of Welds for Performance (API 577)

Repair Welding: Definition and importance of repair welding, condition assessment & feasibility of repair welding, repair welding procedure: preparation, removal of defects, flaw excavation, cleaning and determination of the size of flaw, repair thin-gauge materials and plastics and composites, welding repairs of corrosion damage, welding and other metal deposition methods for dimensional restoration.

Safety and Health: Protection from Heat, Light, Flying Objects and Fume, Prevention of Electric Shock, Prevention of Fire and Explosion, Safety and Health Corresponding to Work Environments, Safety in Welding Robot, Safety in Laser Welding and Cutting

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. 1.ASM Handbook, Volume 6A: Welding Fundamentals and Processes, edited by T. Lienert, 10th edition, ASM International, Materials Park, Ohio, 2011.

Other Suggested Readings:

1. https://www.twi-global.com/technical-knowledge/faqs/faq-i-have-to-weld-a-non-ferrous- metal-what-does-non-ferrous-mean-and-what-thing
2. https://onlinecourses.nptel.ac.in/noc23_me49/preview.

MM26026 **3-0-0 (3)**

Statistics, Quality and Reliability

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe life-cycle cost analysis, optimal maintenance and repair strategies.
CO-2	Evaluate structural components reliability using simulation and sampling techniques.
CO-3	Perform simple SQC calculations applied to real world applications.
CO-4	Apply time-independent reliability formulation for failure probability of structure.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	2	3	-	-	1
CO-2	-	2	3	-	-	1
CO-3	-	2	3	-	-	1
CO-4	-	2	3	-	-	1

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

Syllabus:

Probability and Random Variable: Concepts of probability – Random variables – Baye's Theorem – Standard Probability Distributions – Binomial, Poisson, Normal, Geometric, Exponential distributions – Correlation and Regression.

Statistical Quality Control: Statistical basis for control charts – control limits – control charts and types – control charts for variables, defective and defects – introduction to six sigma – inspections by sampling – OC curves – acceptance sampling plans.

Quality: Basics of quality – Quality philosophy – quality control – quality assurance – design for quality management system – Quality certification and accreditation schemes – total quality management and Taguchi's method – quality standards and procedures

Reliability: Basic concepts of reliability – Reliability Vs Quality – Hazard and failure rate analysis – mean time between failures (MTBF) – mean time to failure (MTTF) –Reliability of systems – Series system, Parallel system, Series-Parallel system.

Design of experiments (DoE): basic principles, full factorial, response surface methodology**.**

Learning Resources:

Text Books:

1. Introduction to Statistical Quality Control, D. C. Montgomery, John Wiley & Sons, 2009, 6ed.
2. Fundamentals of Mathematical Statistics, S. C. Gupta and V. K. Kapoor, S. Chand, 2000, 10ed.

3. Reliability Engineering: Theory and Practice, A. Birolini, Springer, 2010, 6ed

Reference Books:

1. The Six Sigma Handbook, Thomas Pyzdek, McGraw-Hill, 2000.
2. An introduction to Reliability and Maintainability engineering, C. E. Ebeling, 2009, Waveland, 2ed.
3. Total Quality Management, J. S. Oakland, Butterworth–Heinemann Ltd., 2003, 3ed..

Other Suggested Readings:

1. Statistical Quality Control, R.S. Leavenworth, E. L. Grant, Tata McGraw –Hill Education, 2000, 7ed.
2. Non-destructive Evaluation: A Tool in Design, Manufacturing and Service, Don E. Bray and Roderic K. Stanley, CRC Press, 1996.

MM26028 **3-0-0 (3)**

Mechanical Behavior of Weldments

Pre-Requisites: **None**

Course Outcomes:

CO-1	Correlate welding parameters with mechanical properties of welding
CO-2	Analyze failure mechanisms in welding
CO-3	Evaluate of fracture risk in welding

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	2	3	-	-	-
CO-2	-	2	3	-	-	-
CO-3	-	2	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

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

Fatigue: HCF, LCF, Paris law, Fatigue strength, Fatigue failure of the principal welded joints, Factors in welded joint endurance

Evaluation of fracture risks: ductile-brittle transition temperature, elastic linear field and elasto-plastic field fracture, fracture risks in welded joints, Heterogenities of the weld bead, Conditions of specimen craking, Various methods of toughness evaluation.

Learning Resources:

Text Books:

4. George E. Dieter, Mechanical Metallurgy, McGraw Hill, New York, 3rd Edition, 1986. (ISBN 0-07-016853-8) TA405.D53
5. Régis Blondeau (editor), Metallurgy and Mechanics of Welding, Wiley Publishing company 2008, (ISBN: 978-1-118-62374-9)
6. Norman E. Dowling, Mechanical Behavior of Materials, Prentice-Hall, Upper Saddle River, New Jersey, 2nd Edition, 1999. (ISBN0-13-905720-X)

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

MM26030 **3-0-0 (3)**

Computational Methods for Welding and Joining

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the fundamentals of heat transfer, fluid flow, and metallurgical transformations in welding.
CO-2	Apply numerical methods for modeling welding processes.
CO-3	Use simulation software used in welding engineering.
CO-4	Apply modeling and simulation techniques to solve real-world welding problems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	–	2	2	–	–
CO-2	3	2	2	2	–	–
CO-3	2	2	2	3	–	–
CO-4	2	–	2	3	–	–

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

Syllabus:

Overview of welding techniques, principles of heat transfer applied to welding and joining processes, thermal cycles in welding, analytical solutions for temperature distribution; fluid flow fundamentals, weld pool dynamics, Marangoni effect and buoyancy forces, mathematical modelling of weld pool convection, metallurgical aspects of welding, phase prediction using CALPHAD approaches; applications of numerical methods to welding: FEM, FDM and CFD, simulation software tools: ANSYS, ABAQUS; machine learning in welding; residual stresses and its prediction, case studies.

Learning Resources:

Text Books:

1. Robert W. Messler Jr., Principles of Welding: Processes, Physics, Chemistry, and Metallurgy Wiley-VCH, 1999.
2. G. Ravichandran, Finite Element Analysis of Weld Thermal Cycles Using ANSYS, CRC Press, 2020

Reference Books:

1. H. Cerjak, H. K. D. H. Bhadeshia Eds., Mathematical Modelling of Weld Phenomena, CRC Press, 2002
2. Lars-Erik Lindgren, Computational Welding Mechanics, Woodhead Publishing Series in Welding and Other Joining Technologies, 2014

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc21_me36/preview
2. https://archive.nptel.ac.in/courses/113/106/113106067/

EC16062 **3-0-0 (3)**

Signal and Image Processing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss principles, algorithms and applications of digital signal processing (DSP).
CO-2	Explain image acquisition and processing techniques.
CO-3	Discuss image enhancement in both spatial and frequency domains.
CO-4	Use image compression techniques for storage and transmission purpose.
CO-5	Apply image segmentation / morphological operations for object and boundary detection.
CO-6	Select Image processing/DSP techniques for industrial and NDE applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	3	2	2	–	–
CO-2	-	3	2	2	–	–
CO-3	-	3	2	2	–	–
CO-4	-	3	2	2	–	–
CO-5	-	3	3	3	-	-
CO-6	-	3	3	3	-	-

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

Syllabus:

Fundamentals of Digital Signal Processing: Sampling and aliasing, Signal reconstruction, Signal conversion system, Characterization and classification of signals and systems, Z-Transform, inverse Z-Transform, Properties of The Z Transform, Convolution, Correlation, Discrete Fourier transform (DFT), Properties of the DFT.

Digital Image Fundamentals: Overview of Image Processing, Digital Image Representation, Types of Images, Digital Image Processing Operations, Fundamental Steps in Image Processing, Image processing Applications, Digital Imaging System, Elements of Visual perception. Image sensing and Acquisition, Sampling and Quantization, Relationship between pixels.

Image Enhancement: Some basic gray level transformations, Histogram processing, Smoothing and Sharpening spatial filters, Image Enhancement in Frequency Domain: Smoothing and sharpening frequency domain filters, Image Restoration Techniques.

Image compression: Image compression models, Loss-less and Lossy compression, Applications Morphological Image Processing: Dilation and erosion, Opening and closing, some basic morphological

algorithms.

Image Segmentation: Detection of discontinuities, Edge and boundary detection, Thresholding, Region based segmentation.

Case Study: Image Processing for Materials Characterization, detection of various defects in materials, Image processing and DSP for industrial and NDE applications.

Learning Resources:

Text Books:

1. Digital Signal Processing, Principles Algorithms and Applications, Third edition; John G,Proakis and Dimitris G Manolakis (Prentice Hall).
2. S. Salivahanan, A. Vallavaraj, and C. Gnanapriya, Digital Signal Processing Tata McGraw Hill Publication 1st Edition (2010).
3. R. C.Gonzalez, R.E.Woods," Digital Image processing", Pearson edition, Inc3/e,2008.
4. Jayaraman, Subramania, S. Esakkirajan, and T. Veerakumar. Digital image processing. Vol. 7014. New Delhi: Tata McGraw Hill Education, 2009.

Reference Books:

1. J.C. Russ," The Image Processing Handbook", (5/e), CRC, 2006
2. R.C.Gonzalez & R.E. Woods; "Digital Image Processing with MATLAB", Prentice Hall, 2003
3. Anand Kumar, Digital Signal Processing, PHI Learning Pvt. Ltd. 2013.
4. S. Sridhar, Digital Image Processing, Oxford University Press, Second Edition, 2012.
5. A.K.Jain," Fundamentals of Digital Image Processing", PHI,1995.

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

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	-	-
CO-2	3	-	-	2	-	-
CO-3	3	-	-	2	-	-
CO-4	3	-	3	2	-	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, materials used in additive manufacturing, challenges in additive manufacturing.

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), 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 (Solid-state sintering, chemically induced sintering, liquid phase sintering, Full melting), 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, brief information on characterization techniques used in additive manufacturing, applications of additive manufacturing in rapid prototyping, rapid manufacturing, rapid tooling, repairing and coating.

Future scope in Additive Manufacturing: Evaluation of additive manufactured structures/ components, scope of AM in various fields. Its 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.
5. L.W. Liou, F.W. Liou: Rapid Prototyping and Engineering applications: A toolbox for prototype development, CRC Press, 2007.
6. A.K. Kamrani, E.A. Nasr: Rapid Prototyping- Theory and Practice, Springer, 2006.
7. P.D. Hilton, P.F. Jacobs: Rapid Tooling- Technologies and Industrial Applications, CRC Press, 2000.
8. Ian Gibson, David W Rosen, Brent Stucker: Additive Manufacturing Technologies- Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010
9. D.T. Pham, S.S. Dimov: Rapid Manufacturing- The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer, 2001.C.K. Chua, K.F. Leong, C.S. Lim: Rapid prototyping- Principles and applications, 3rd Ed., World Scientific Publishers, 2010.

Reference Books:

1. Additive Manufacturing Processes, Editor: David L. Bourell, William Frazier, Howard Kuhn, and Mohsen Seifi, ASM Hand Book, Volume 24, ASM International, 2020Title of the Text Book, Author(s), Publisher, Year and Edition

Other Suggested Readings:

1. https://additivemanufacturing.com/basics/
2. https://www.additivemanufacturing.media/

MM16038 **3-0-0 (3)**

Design and Selection of Advanced Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss materials selection methodologies
CO-2	Apply statistics in materials selection
CO-3	Analyze the influence of composition, heat treatment and microstructure on the properties of engineering materials
CO-4	Select suitable materials for structural and functional applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	-	1	2	-	-
CO-2	-	-	1	2	-	-
CO-3	-	-	3	3	2	-
CO-4	-	-	3	3	2	-

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

Syllabus:

Revision of engineering materials: Classification of materials- metals and alloys, ceramics, polymers and composites, Importance of materials selection and metallurgical design, Properties and applications of plain carbon steels and common non-ferrous alloys.

Criteria for selection of materials: Ashby charts for materials selection, application of statistics in materials,specification of steels, Composition, heat treatment, microstructure and properties of ferrous and non- ferrous alloys, ceramics, and polymers for light and heavy structural, corrosion-resistant, high temperature, low-temperature, and cryogenic, wear-resistant, magnetic, electrical and electronic applications, pressure vessels and boilers, bearings, tools, medical implants and prostheses application, Composites, shape memory alloys, metallic glasses, nanocrystalline materials.

Learning Resources:

Text Books:

1. M.F. Ashby, Engineering Materials, 4th Edition, Elsevier, 2005.
2. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 2005.
3. Pat L. Mangonon, The Principles of Materials Selection and Design, Prentice Hall International, Inc.1999.

Reference Books:

1. ASM Metals Handbook, Vol.20: Materials Selection and Design, ASM, 1997.

Other Suggested Readings:

1. https://www.youtube.com/watch?v=9RQkvcsRzbo