NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

B.Tech. in

METALLURGICAL AND MATERIALS ENGINEERING

SCHEME OF INSTRUCTION AND SYLLABI

(Effective from 2021-22)

DEPARTMENT OF

METALLURGICAL AND MATERIALS ENGINEERING

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.

DEPARTMENT OF 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.

Department of Metallurgical and Materials Engineering

Brief about the Department:

The Department of Metallurgical and Materials Engineering (formerly known as Department of Metallurgical Engineering) was established in the year 1965 with an intake of 30 BTech students. A post-graduate programme in Industrial Metallurgy was introduced in the year 1983 with an intake of 10 students. The Department is also offering a Ph. D. programme since 1983. Department has also introduced another M.Tech. programme in Materials Technology from the academic year 2011-2012. The main areas of study in Metallurgical and Materials Engineering include Physical Metallurgy, Extractive Metallurgy (Iron, Steel and Non-ferrous Metal extraction), Mineral Processing, Heat Treatment of Steels, Manufacturing Technologies (Metal Casting, Metal Forming, Powder Metallurgy and Welding), Mechanical Metallurgy (includes Material Testing – Destructive and Non-Destructive), Corrosion Engineering, and Materials Characterization Techniques etc. In view of the increasing demand in materials development, the department has introduced new subjects in its curriculum with materials background in the year 2004. Accordingly, the scheme of instruction has been enriched with subjects on advanced materials like Composite Materials, Ceramics, Polymers, Nanomaterials, Computer Applications in Metallurgical and Materials Engineering etc. in addition to the above main areas. The laboratories of the Department are well equipped with the state-of-the-art equipment.

List of Programs offered by the Department:

Program	Title of the Program
B.Tech.	Metallurgical and Materials Engineering
M.Tech.	Industrial Metallurgy
M.Tech.	Materials technology
BTech+MTech	Metallurgical and Materials Engineering
PG Diploma	Industrial Metallurgy
PG Diploma	Materials technology
Ph.D.	Metallurgical and Materials Engineering

Note: Refer to the following weblink for Rules and Regulations of B.Tech. program:
https://www.nitw.ac.in/media/uploads/2021/08/27/btech_rules-and-regulations-2021-22.pdf

B.Tech. – METALLURGICAL AND MATERIALS ENGINEERING

Program Outcomes (POs)

At the end of the program, the student will be able to:

PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, metallurgical and materials engineering to the solution of complex engineering problems
PO2	**Problem analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences
PO3	**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
PO4	**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
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex metallurgical and materials engineering activities with an understanding of the limitations
PO6	**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
PO7	**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
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**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.
PO11	**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

PO12	**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 (PSOs)

PSO1	Select/design processes for extraction and manufacturing of ferrous and non-ferrous metals and alloys
PSO2	Apply thermodynamic, physical and mechanical metallurgy principles to improve the performance and service life of the components
PSO3	Process and develop ceramic, polymer, composites and functional materials for specific applications
PSO4	Evaluate and assess structure and properties of materials using characterization techniques

DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING

B.TECH. IN METALLURGICAL AND MATERIALS ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES

PEO1	Apply knowledge of basic sciences, metallurgical and materials engineering for the development of materials through extraction, refining, processing and manufacturing.
PEO2	Model, design, process, characterize and evaluate materials for generic, industrial and strategic applications.
PEO3	Work effectively as an individual and in a team in inter- and multi-disciplinary projects with ethics and professionalism
PEO4	Pursue life-long learning to enhance knowledge and professional skills for career growth with social and environmental responsibility

Program Articulation Matrix

Mission Statement	PEO1	PEO2	PEO3	PEO4
Provide outstanding technical education for analysis, design and operation of metallurgical and materials systems.	3	3	-	-
Keep abreast with rapid strides of technology and improve academic standards through innovative teaching and learning processes.	3	3	-	3
Engage in quality research in metallurgical, materials and allied engineering areas.	3	3	3	-
Develop linkages with leading academic, research, and industrial organizations for societal benefit.	-	-	3	3

SCHEME OF INSTRUCTION

B.Tech. (Metallurgical and Materials Engineering) Course Structure

I – Year: I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MA134	Matrix theory, Calculus and Ordinary Differential Equations	3	0	0	3	BSC
2	HS132	English for Technical Communication	2	0	2	3	HSC
3	CE101	Engineering Mechanics	3	0	0	3	ESC
4	CY137	Chemistry for Metallurgists	3	0	2	4	BSC
5	EC131	Basic Electronic Engineering	3	0	0	3	ESC
6	MM101	Introduction to Materials Science and Engineering	2	0	0	2	PCC
9	IC001	Induction Program *				0	MNC
10	IC101	Extra Academic Activity *	0	0	2	0	MNC
		Total				**18**	

I – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MA184	Integral Calculus and Laplace Transforms	3	0	0	3	BSC
2	ME131	Basic Mechanical Engineering	3	0	0	3	ESC
3	ME132	Engineering Graphics	1	0	4	3	ESC
4	PH183	Physics for Metallurgists	2	0	2	3	BSC
5	MM151	Mineral Processing	2	0	0	2	PCC
6	CS181	Problem Solving and Computer Programming	3	0	2	4	ESC
7	ME134	Workshop Practice	0	1	2	2	ESC
8	IC151	EAA*	0	0	2	0	MNC
		Total				**20**	

* MNC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/mnc_1st-year.pdf

Note: BSC – Basic Science Courses
ESC – Engineering Science Courses
HSC – Humanities and Social Science Courses
MNC – Mandatory Non-credit Courses
PCC - Professional Core Courses
EAA- Extra Academic Activities

SCHEME OF INSTRUCTION

B.Tech. (Metallurgical and Materials Engineering) Course Structure

II – Year: I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MA235	Transforms, Complex Variables and Partial Differential Equations	3	0	0	3	BSC
2	MM201	Physical Metallurgy	3	0	0	3	PCC
3	MM202	Unit Processes in Extractive Metallurgy	3	0	0	3	PCC
4	MM203	Metallurgical Thermodynamics	2	1	0	3	PCC
5	MM204	Transport Phenomena	2	1	0	3	PCC
6	EE232	Fundamentals of Electrical Engineering	3	0	0	3	ESC
7	MM205	Physical Metallurgy and Metallography Laboratory	0	1	2	2	PCC
8	MM206	Unit Processes in Extractive Metallurgy Laboratory	0	1	2	2	PCC
9	EE233	Basic Electrical Engineering Laboratory	0	0	3	1.5	ESC
10		MNC-4 *				0	MNC
		Total				**23.5**	

II – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MA285	Statistics and Numerical Methods	2	0	0	2	BSC
2	MM251	Phase Transformations and Heat Treatment	3	0	0	3	PCC
3	MM252	Solidification Processing	3	0	0	3	PCC
4	MM253	Iron Making Technology	3	0	0	3	PCC
5	MM254	Electronic and Magnetic Materials	3	0	0	3	PCC
6	CH281	Polymer Technology	3	0	0	3	PCC
7	MM255	Phase Transformations and Heat Treatment Laboratory	0	1	2	2	PCC
8	MM256	Solidification Processing Laboratory	0	1	2	2	PCC
9	EC283	Basic Electronics Laboratory	0	0	3	1.5	ESC
		Total				**22.5**	

Note: Students can do the "Summer/Research Internship/EPICS Project MM406" either in the II Year summer or III Year summer. However, grades will be reflected in the IV year I semester grade sheet

* MNC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/mnc_2nd-year.pdf

SCHEME OF INSTRUCTION

B.Tech. (Metallurgical and Materials Engineering) Course Structure

III – Year: I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	SM335	Business Economics and Finance for Engineers	3	0	0	3	HSC
2	MM301	Steel Making Technology	3	0	0	3	PCC
3	MM302	Mechanical Behaviour of Materials	3	0	0	3	PCC
4	MM303	Powder Metallurgy	3	0	0	3	PCC
5		Department Elective I	3	0	0	3	PEC
6		Department Elective II	3	0	0	3	PEC
7	MM304	Mechanical Behaviour of Materials Laboratory	0	1	2	2	PCC
8	MM305	Powder Metallurgy Laboratory	0	1	2	2	PCC
9		MNC 5 *				0	MNC
		Total				**22**	

III – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	MM351	Corrosion Engineering	3	0	0	3	PCC
2	MM352	Computational Materials Engineering	3	0	0	3	PCC
3	MM353	Materials Characterization	3	0	0	3	PCC
4	MM354	Ceramics and Composites Technology	3	0	0	3	PCC
5		Department Elective III	3	0	0	3	PEC
6		Open Elective I #	3	0	0	3	OEC
7	MM355	Computational Materials Engineering Laboratory	0	1	2	2	PCC
8	MM356	Materials Characterization Laboratory	0	1	2	2	PCC
9	MM357	Corrosion Engineering Laboratory	0	1	2	2	PCC
		Total				**24**	

Note: Students can do the “Summer/Research Internship/EPICS Project- MM406” either in the II Year summer or III Year summer. However, grades will be reflected in the IV year I semester grade sheet

* MNC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/mnc_3rd-year.pdf

OEC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/open-elective-1_vi-sem.pdf

SCHEME OF INSTRUCTION

B.Tech. (Metallurgical and Materials Engineering) Course Structure

IV – Year: I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1.	SM435	Industrial Management and Methods	3	0	0	3	HSC
2.	MM401	Metal Joining	3	0	0	3	PCC
3.	MM402	Metal forming	3	0	0	3	PCC
4.	MM403	Non Ferrous Extractive Metallurgy	3	0	0	3	PCC
5.	MM404	Non-Destructive Testing Laboratory	0	0	2	1	PCC
6.	MM405	Metal Processing Laboratory	0	0	2	1	PCC
7.		Open Elective II #	3	0	0	3	OEC
8.	MM406	Summer/Research Internship/EPICS Project				2	PCC
		Total				**19**	

Note: Students can do the "Summer/Research Internship/EPICS Project" either in the II Year summer or III Year summer. However, grades will be reflected in the IV year I semester grade sheet

IV – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1		Department Elective IV	3	0	0	3	PEC
2		Department Elective V	3	0	0	3	PEC
3	MM498	Seminar	0	0	2	1	PCC
4	MM499	Project Work @	0	0	8	4	PW
		Total	**6**	**0**	**10**	**11**	

OEC weblink: https://www.nitw.ac.in/media/uploads/2021/10/22/open-elective-2_vii-sem.pdf

@ NOTE: Refer to the following link for the guidelines to prepare dissertation report:
https://www.nitw.ac.in/media/uploads/2021/08/27/ug_project-report-format_55vW5pL.pdf

Professional Elective Courses:

Semester	Elective Number	Course Code	Course Title
V	I/II	MM311	Physical Metallurgy of Non-Ferrous Metals and Alloys
		MM312	Fuels and Refractories
		MM313	Materials for Bio-Applications
		MM314	Smart Materials
		MM315	Advanced Metallurgical Thermodynamics
		MM316	Functional Materials
		MM317	Energy Materials
VI	III	ME361	Finite Element Method
		MM362	Creep, Fatigue and Fracture
		MM363	Ferroalloy Technology
		MM364	Atom Probe Tomography
		MM365	Non-Destructive Testing
		MM366	Machine Learning for Materials Engineering
VIII	IV/V	MM461	Advanced Engineering Materials
		MM462	Materials for Extreme Environments
		MM463	Surface Engineering
		MM464	Nuclear Metallurgy
		MM465	Refractory and Rare Metal Extraction
		MM466	Pollution and its Control in Metallurgical Industries
		MM467	Metallurgical Waste Recycling
		MM468	Materials Selection and Design
		MM469	High Temperature Materials
		MM470	Advanced Materials Characterization Techniques
		MM471	Metallurgical Failure Analysis
		MM472	Introduction to Nano Science and Technology

B. Tech+M. Tech (Dual Degree)

Analysis and distribution of credit

- Course Intake (2 or 3) seats **permitted in a specialization** and the degree awarded will be *M. Tech. in Metallurgy and Material Engineering.*
    - BTech students doing Honors (18 credits) are permitted to opt for M. Tech.
    - They need not do project as part of their B. Tech.
    - M. Tech project will start from 8th semester.
    - Total credits required = 200
    - Credits for B. Tech = 160
    - Credit left for 5th year = 200 - [160(B.Tech) - 4(project credit) + 18(Honors)] = 26

Distribution of 26 credit for the course

- 8th semester - 4 credits (M. Tech dissertation) {Involving problem identification and Lit Rev.}
- 9th semester - 8 credits (M. Tech dissertation)
- 10th semester - 14 credits (M. Tech dissertation)

- *Note - M. Tech. dissertation supervisor should be decided in 7th semester.*
- If student wants to opt out of the course he/she will be allowed by permission. Then M. Tech dissertation is changed to B. Tech dissertation.

B.Tech to PhD

- Any B. Tech student is eligible given they have **CGPA** more than or equal to (**8.0** for general and **8.00** for SC/ST) with a valid **GATE** score.
- Based on the merit among the applicants and also performance in interview a **max of 2 seat**s are permitted from the No. of PhD admissions allotted to the department.
- The student has to complete 18 credits and **all the other rules and regulations same as the other full time PhD scholar.**
- Note- The guidelines for the PhD program can be referred in Guidelines for curriculum revision approved by Senate in its 114th meeting (Topic no. IV. PhD program on page 7 of the pdf file).

I – Year: I – Semester

Course Code: MA134	MATRIX THEORY, CALCULUS AND ORDINARY DIFFERENTIAL EQUATIONS	L-T-P: Cr 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Solve the consistent system of linear equations
CO2	Apply orthogonal and congruent transformations to a quadratic form
CO3	Determine the power series expansion of a given function
CO4	Find the maxima and minima of multivariable functions
CO5	Solve arbitrary order linear differential equations with constant coefficients
CO6	Apply the concepts in solving physical problems arising in engineering

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-
CO2	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-
CO3	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-
CO4	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-
CO5	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-
CO6	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Matrix Theory: Linear dependence and independence of vectors; Rank of a matrix; Consistency of the system of linear equations; Eigenvalues and eigenvectors of a matrix; Caley-Hamilton theorem and its applications; Reduction to diagonal form; Reduction of a quadratic form to canonical form - orthogonal transformation and congruent transformation; Properties of complex matrices - Hermitian, skew-Hermitian and Unitary matrices. (14)

Differential Calculus: Taylor's theorem with remainders; Taylor's and Maclaurin's expansions; Asymptotes; Curvature; Curve tracing; Functions of several variables - partial differentiation; total differentiation; Euler's theorem and generalization; Change of variables - Jacobians; maxima and minima of functions of several variables (2 and 3 variables) - Lagrange's method of multipliers. (14)

Ordinary Differential Equations: Geometric interpretation of solutions of first order ODE $y' = f(x, y)$; Exact differential equations; integrating factors; orthogonal trajectories; Higher order linear differential equations with constant coefficients - homogeneous and non-homogeneous; Euler and Cauchy's differential equations; Method of variation of parameters; System of linear differential equations. (14)

Text Books:

1. R. K. Jain and S. R. K. Iyengar, "Advanced Engineering Mathematics", Fifth Edition, Narosa Publishing House, 2016
2. Erwin Kreyszig, "Advanced Engineering Mathematics", Eighth Edition, John Wiley and Sons, 2015
3. B. S. Grewal, "Higher Engineering Mathematics", Khanna Publications, 2015

Course Code: HS132	ENGLISH FOR TECHNICAL COMMUNICATION	L-T-P: Cr 2-0-2: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Understand and learn the nuances of paragraph writing and sample different types of paragraphs that are commonly used; learn to write an effective paragraph using devices of coherence and cohesion; Understand the meaning of idioms and phrasal verbs and use them in context; learn to use sentences unambiguously.
CO2	Learn to construct an effective résumé and cover letter; learn the finer points and dos and don'ts of résumé writing
CO3	Master the skills and sub skills of reading; use strategies for reading effectively: skimming, scanning, mapping; Learn to analyze vocabulary through contextual clues, word parts, analogies; demonstrate the ability to employ a range of critical reading skills
CO4	Learn the importance and use of reported speech in a wide range of contexts; use active and passive voice in engineering and scientific contexts when compiling lab reports, project reports, writing technical papers, etc.
CO5	Learn the structure and format of technical reports; distinguish technical reports from other types of reports such as business reports, analytical reports, progress reports, etc. learn to write technical reports on a variety of topics.
CO6	Learn to interpret graphs of various kinds and pie charts and diagrams; learn to use terms of comparison and contrast when interpreting charts, bar diagrams and graphs

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-
CO2	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-
CO3	-	-	-	-	-	-	-	-	1	3	1	2	-	-	-	-
CO4	-	-	-	-	-	-	-	-	1	3	1	2	-	-	-	-
CO5	-	-	-	-	-	-	-	-	1	3	1	-	-	-	-	-
CO6	-	-	-	-	-	-	-	-	1	3	1	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. **Grammar Principles** (Correction of sentences, Concord) and Vocabulary Building (synonyms and antonyms): Idioms and Phrasal verbs--patterns of use and suggestions for effective employment in varied contexts
2. **Effective Sentence Construction** - strategies for bringing variety and clarity in sentences removing ambiguity - editing long sentences for brevity and clarity
3. **Reported speech**- contexts for use of reported speech - its impact on audiences and readers active and passive voice- reasons for preference for passive voice in scientific English
4. **Paragraph-writing**: Definition of paragraph and types- features of a good paragraph - unity oftheme-coherence- linking devices- direction- patterns of development.
5. **Note-making** - definition- the need for note-making - its benefits - various note formats- like tree diagram, block or list notes, tables, etc.
6. **Letter-Writing**: Its importance in the context of other channels of communication- qualities of effective letters-types -personal, official, letters for various purposes- emphasis on letter of application for jobs - cover letter and resume types -examples and exercises
7. **Reading techniques**: Definition- Skills and sub-skills of reading- Skimming and Scanning – their uses and purposes- examples and exercises.
8. **Reading Comprehension** - reading silently and with understanding- process of comprehension types of comprehension questions.
9. **Features of Technical English** - description of technical objects and process- Report-Writing definition- purpose -types- structure- formal and informal reports- stages in developing report proposal, progress and final reports-examples and exercises.

10. **Book Reviews**- Oral and written review of a chosen novel/play/movie- focus on appropriate vocabulary and structure - language items like special vocabulary and idioms used

Language laboratory

1. **English Sound System** -vowels, consonants, Diphthongs, phonetic symbols- using dictionary to decode phonetic transcription-- Received Pronunciation, its value and relevance- transcription of exercises

2. **Stress and Intonation** -word and sentence stress - their role and importance in spoken English Intonation in spoken English -definition, patterns of intonation- -falling, rising, etc.-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.

Text Books/ Reference Books:

1. English for Engineers and Technologists (Combined Edition, Vol. 1 and 2), Orient Blackswan, 2006.
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.

Software

1. Clear Pronunciation - Part-1 *Learn to Speak English.*
2. Clear Pronunciation - Part-2 *Speak Clearly with Confidence*
3. Study Skills4. English Pronunciation

Course Code: CE101	ENGINEERING MECHANICS	L-T-P: Cr 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Determine the resultant force and moment for a given system of forces.
CO2	Analyze planar and spatial systems to determine the forces in members of trusses, frames and problems related to friction.
CO3	Calculate the motion characteristics of a body subjected to a given force system.
CO4	Determine the deformation of a shaft using material constants.
CO5	Determine the centroid and second moment of area.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Specification of force vector, Formation of Force Vectors, Moment of Force – Cross product – Problems, Resultant of a general force system in space, Degrees of freedom - Equilibrium Equations, Kinematics – Kinetics – De' Alemberts principle, Degree of Constraints – Free body diagrams.

Spatial Force systems: Concurrent force systems - Equilibrium equations – Problems, Problems (Vector approach) – Tension Coefficient method, Problems (Tension Coefficient method), Parallel force systems - problems, Center of Parallel force system – Problems.

Coplanar Force Systems: Introduction – Equilibrium equations – All systems, Problems on Coplanar Concurrent force system, Coplanar Parallel force system, Coplanar General force system – Point of action, Method of joints, Method of sections, Method of sections, Method of members, Friction – Coulombs laws of dry friction – Limiting friction, Problems on Wedge friction, Belt Friction-problems.

Mechanics of Deformable Bodies: Stress & Strain at a point- Normal and shear stresses, Axial deformations – Problems on prismatic shaft, tapered shaft and deformation due to self-weight, Deformation of Stepped shaft due to axial loading, Poisson's Ratio – Bulk Modulus - Problems, change in dimensions and volume.

Centroid & Moment of Inertia: Centroid and M.I – Arial – Radius of Gyration, Parallel axis– Perpendicular axis theorem – Simple Problems.

Dynamics of Particles: Rectilinear Motion – Kinematics Problems, Kinetics – Problems, Work & Energy – Impulse Moment, Curvilinear Motion – Normal and tangential components.

Text Books:

1. Engineering Mechanics (In SI Units), S. Timoshenko, D.H. Young, J.V. Rao and Sukumar Pati, McGraw Hill Publishers, 2017,5th Edition.
2. Vector Mechanics for Engineers - Statics and Dynamics, Ferdinand P. Beer, E. Russell Johnston Jr., et al., McGraw Hill Publishers, 2019, 12th Edition.
3. Mechanics of Materials, Gere and Timoshenko, CBS Publishers, 2011, 2nd Edition,.

Reference Books:

1. Mechanics of Materials (SI Edition), R. C. Hibbeler, Pearson publication, 2018.

2. Engineering Mechanics: Statics, SI Version, J. L. Meriam, L. G. Kraige, et al., Wiley India Edition, 2017
3. Engineering Mechanics: Dynamics, SI Version, J.L. Meriam , L.G. Kraige, et al., Wiley India Edition, 2018
4. Engineering Mechanics, S S Bhavikatti, New Age International Private Limited, 2021, 8th edition.

Online Resources:
https://nptel.ac.in/courses/122/104/122104015/
https://nptel.ac.in/courses/112/106/112106180/

Course Code: CY137	CHEMISTRY FOR METALLURGISTS	L-T-P: Cr 3-0-2: 4

Pre-Requisites: None

Course Outcomes:

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

CO1	Understand the basic concepts of physical chemistry relevant to materials synthesis
CO2	Comprehend the concepts of instrumentation principles, Spectroscopy and procedures involved in characterization of materials
CO3	Apply electrochemical concepts used in synthesis and operation of electrochemical energy systems
CO4	Develop materials for engineering applications using the concepts in chemistry
CO5	Select a suitable methodology for the estimation of metal content, iodine content, active chlorine or hardness of water
CO6	Analyse acids, bases, redox compounds, etc. using instrumental methods

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	2	2	1	2
CO3	3	2	-	-	-	-	-	-	-	-	-	-	2	2	1	1
CO4	3	-	-	-	-	-	-	-	-	-	-	-	2	2	1	-
CO5	3	-	-	-	3	-	-	-	-	-	-	-	2	3	-	2
CO6	3	-	-	-	3	-	-	-	-	-	-	-	2	3	-	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Unit No	Title and Contents	Hrs.
1.	**Chemical Kinetics**: Basics of Chemical Kinetics, First Order, Pseudo first order, Second Order Reactions, Derivation of Second order reaction-rate constant, units, half-life period, Methods of Determining Order of a Reaction, Effect of Temperature on Reaction Rates. Theories of Reaction Rates. Examples and numerical problems.	**7**
2.	**Materials Chemistry:** Semiconducting materials; Insulators & magnetic materials: Liquid crystals; Super conductors. Trace Metal Analysis**:** Atomic Spectroscopy (AES, AAS), ICP-MS.	**9**
3.	**Electrochemical Energy Systems:** Introduction to Electrochemistry: Electrical conductance, migration of ions, theories of ionization, redox potentials, Nernst's law and its applications. Electrochemical energy sources**:** Introduction to battery and fuel cell, Batteries: Electrode potential, primary and Secondary cell, Lithium ion battery; Fuel cell types.	**9**
4.	**Polymer Chemistry** Polymers: Introduction-classification, polymerization- Types, mechanism of polymerization, Preparation, Properties and applications.	**4**
5.	**Spectroscopic Methods of Analysis:** UV-VIS spectroscopy, Infrared spectroscopy, NMR spectroscopy.	**8**
6.	**Green Technologies:** Principles of Green Chemistry. Green methods in material production. Nanoparticles synthesis via green / eco-friendly methods, waste water treatment via microbes, recycling of industrial waste using emerging green technologies.	**5**

Learning Resources:

Text Books :

1. A Text Book of Engineering Chemistry, Shashi Chawla, Danpathrao & Co. Publications, 6th India reprint edition, 2007
2. Text Book of Engineering Chemistry, Ashutosh Kar, ED-Tech Publications, 2018
3. Organic Spectroscopy, William Kemp, Macmillan Education, Limited, 2017

Reference Books :

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

Course Code: EC131	BASIC ELECTRONIC ENGINEERING	L-T-P: Cr 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Comprehend the characteristics of semiconductor devices, and operational amplifiers.
CO2	Describe the working principles of amplifiers.
CO3	Design simple combinational and basics of sequential logic circuits.
CO4	Explain the principles of electronic measuring instruments and transducers.
CO5	Apply the principles of electronic communication.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2
CO2	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2
CO3	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2
CO4	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2
CO5	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Electronics Systems: Introduction to electronics, review of p-n junction operation, diode applications, Zener diode as regulator.

Transistor and applications: Introduction to transistors, BJT (Bipolar Junction Transistor) Characteristics, biasing and applications, simple RC coupled amplifier and frequency response. FET and MOSFET characteristics and applications.

Feedback in Electronic Systems: Open loop and closed loop systems, Negative and positive feedback, merits and demerits, Principles of LC and RC oscillators.

Integrated Circuits: Operational amplifiers – characteristics and linear applications

Digital Circuits: Number systems and logic gates, Combinational Logic circuits, Flip-Flops, counters and shift registers, data converters, Analog to Digital and Digital to Analog converters (ADC/DACs), Introduction to microprocessors and microcontrollers.

Laboratory measuring instruments: principles of digital multi-meters, Cathode ray oscilloscopes (CROs).

Electronics Instrumentation: Measurement, Sensors, principles of LVDT, strain gauge and thermocouples. Introduction to data acquisition system.

Principles of Communication: Need for Modulation, Definitions of various Modulation and Demodulation techniques, AM radio transmitter and receiver, brief understanding of FM and mobile communications.

Text Books:

1. Salivahanan, N Suresh Kumar, Electronic Devices and circuits, 3rd Edition, McGraw Hill publications
2. Bhargava N. N., D C Kulshreshtha and S C Gupta, Basic Electronics & Linear Circuits, 2nd Edition, Tata McGraw Hill, 2013.
3. Malvino and Brown, “Digital Computer electronics” Mcgraw Hill, 3rd Edition.
4. Keneddy and Davis, “Electronic Communication Systems” Mcgraw Hill, 4th Edition.
5. Helfrick and Cooper, “ Modern Electronic Instrumentation and Measurement Techniques” PHI, 2011

Reference Books:

1. Neil Storey, Electronics A Systems Approach, 4th Edition, Pearson Education Publishing Company Pvt Ltd

Course Code: MM101	INTRODUCTION TO MATERIAL SCIENCE AND ENGINEERING	L-T-P: Cr 2-0-0: 2

Pre-Requisites: None

Course Outcomes:

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

CO1 List various advanced materials and their need for building modern industry.
CO2 Illustrate crystal systems and relevant calculations.
CO3 Categorise imperfections in solids.
CO4 Examine the types of solid solutions and their formation.
CO5 Summarize properties of engineering materials.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-
CO5	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.

Bonding in solids

Metallic bond, ionic bond, covalent bond, van der Waals bond, mixed bond; forces between atoms/molecules.

The Structure of Crystalline Solids

Introduction, Crystal Structures - Fundamental Concepts, Unit Cells, Metallic Crystal Structures, Density Computations, Polymorphism and Allotropy, Crystal Systems; Crystallographic points, directions, and planes - Point Coordinates, Crystallographic Directions, Crystallographic Planes, Linear and Planar Densities, Close-Packed Crystal Structures; Crystalline and noncrystalline Materials - Single Crystals, Polycrystalline Materials, Anisotropy, Noncrystalline Solids.

Structure of Ceramics and Glasses, Structure of Polymers, Structure of Composites

Imperfections in Solids

Introduction, Point defects - Vacancies and Self-Interstitials, Linear Defects – Dislocations; Interfacial (planar) Defects, Bulk or Volume Defects, effect of imperfections on metal properties.

Solid Solutions:

Introduction and definition, types of solid solutions – substitutional solid solutions, interstitial solid solutions, Hume Rothery's rules, intermediate phases, solid solution alloys, mechanical mixtures.

Properties of materials

Physical properties, Thermal Properties, Band Theory of Metals, Electrical Properties, Magnetic Properties, Optical Properties, Mechanical properties, Technological properties.

Text Books:

1. Materials Science and Engineering-An Introduction, William D. Callister, Jr., John Wiley & Sons, Inc., 2007, 7th Edition.
2. The Science and Engineering of Materials, Donald R. Askeland, Pradeep P. Phule, Thomson Learning, 2007, 5th Edition.

3. An introduction to materials engineering and science: for chemical and materials engineers, Brian S. Mitchell, John Wiley & Sons, Inc., 2004
4. Materials Science and Engineering – A First Course, V. Raghavan, Prentice Hall of India Private Limited, 2015, 6th Edition.
5. Materials Science and Engineering, G. S. Upadhyaya and Anish Upadhyaya, Viva Books Private Limited, 2006

I – Year: II – Semester

Course Code: MA184	INTEGRAL CALCULUS AND LAPLACE TRANSFORMS	L-T-P: Cr 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Analyze improper integrals
CO2	Evaluate multiple integrals in various coordinate systems
CO3	Apply the concepts of gradient, divergence and curl to formulate engineering problems
CO4	Convert line integrals into surface integrals and surface integrals into volume integrals
CO5	Apply Laplace transforms to solve physical problems arising in engineering

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-
CO2	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-
CO3	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-
CO4	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-
CO5	3	3	1	2	1	-	-	-	-	-	-	-	2	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Integral Calculus: Convergence of improper integrals; Beta and Gamma integrals; Differentiation under integral sign; Double and Triple integrals - computation of surface areas and volumes; 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; Line and Surface 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 function, impulse function, periodic function; 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 etc.

Text Books / Reference Books

1. R. K. Jain and S. R. K. Iyengar, "Advanced Engineering Mathematics", Narosa Publishing House, 5th Edition, 2016.
2. Erwin Kreyszig, "Advanced Engineering Mathematics", John Wiley and Sons, 8th Edition, 2015.
3. B. S. Grewal, "Higher Engineering Mathematics", Khanna Publications, 2015.

Course Code: ME131	BASIC MECHANICAL ENGINEERING	L-T-P: Cr 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Explain thermodynamic principles and components of a thermal power plant
CO2	Identify engineering materials, their properties, manufacturing methods encountered in engineering practice
CO3	Describe the mechanical power transmission involving belt, rope, chain and gear drives.
CO4	Illustrate automobile components and their operation.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Engineering Materials: Introduction to Engineering Materials, Classification and Properties

Manufacturing Processes: Castings - Patterns & Moulding, Hot Working and Cold Working, Metal Forming processes: Extrusion, Drawing, Rolling, Forging, Welding - Arc Welding & Gas Welding, Soldering, Brazing.

Machine Tools: Lathe - Types - Operations, Problems on Machining Time Calculations, Drilling M/c - Types - Operations, Milling M/c - Types - Operations - Up & Down Milling, Shaping M/c - Operations- Quick Return Mechanism, Planer M/c.- Operations-Shaper Vs Planer, Grinding M/c-Operations. Introduction to NC/CNC Machines, 3D Printing

Power Transmission: Transmission of Power, Belt Drives, Gears and Gear Trains -Simple Problems

Fasteners and Bearings: Fasteners - Types and Applications, Bearings - Types and Selection,

Thermodynamics: Energy Sources - Conventional/Renewable, Thermodynamics - System, State, Properties, Thermodynamic Equilibrium, Process & Cycle, Zeroth law of Thermodynamics, Work & Heat, First law - Cyclic process, Change of State, C_p, C_v, Limitations of First law, Thermal Reservoirs, Heat Engine, Heat Pump/Refrigerator, Efficiency/COP, Second law, PMM2, Carnot Cycle, Entropy - T-S and P-V diagrams.

Thermal Power Plant: Layout of Thermal Power Plant & Four circuits - Rankine cycle, T-S & P-V diagrams, Boilers - Babcock & Wilcox, Cochran Boilers, Comparison of Fire Tube &Water Tube Boilers, Steam Turbines - Impulse Vs. Reaction, Compounding - Pressure & Velocity Compounding, Condensers - Jet Condenser and Surface Condenser; Cooling Towers

I.C. Engines: 2-Stroke & 4-Stroke Engines, P-v Diagram; S.I. Engine, C.I. Engine, Differences Refrigeration: Vapor Compression Refrigeration Cycle - Refrigerants, Desirable Properties of Refrigerants

Heat Transfer: Modes of Heat Transfer, Thermal Resistance Concept, Composite Walls & Cylinders, and Overall Heat Transfer Coefficient - problems

Automobile Engineering: Layout of an Automobile, Transmission, Clutch, Differential, Internal Expanding Shoe Brake

Text book:

Elements of Mechanical Engineering- M.L.Mathur, F.S.Mehta and R.P.Tiwari, Jain Brothers, New Delhi

Reference books:

1. Engineering Heat Transfer-Gupta & Prakash, New Chand Bros., New Delhi

2. Workshop Technology (Vol. 1&2)-B.S.Raghuvanshi, Dhanpath Rai & Sons, New Delhi

Course Code: ME132	ENGINEERING GRAPHICS	L-T-P: Cr 1-0-4: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Apply BIS standards and conventions in 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 is defined to the reference plane using CAD environment
CO4	Analyse the internal details of an object through sectional views in CAD environment.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction:

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

Orthographic Projection:

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

Projection of Points:

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

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

Fundamentals of AutoCAD: Introduction to Auto-CAD, DRAW tools, MODIFY tools, TEXT, DIMENSION, PROPERTIES (AutoCAD)

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

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

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

Text Books:

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

Reference Books:

1. Agarwal, B, Engineering Drawing, Second edition, McGraw Hill Education, 2015
2. Prof. Sham Tickoo, AutoCAD 2017 for Engineers & Designers, 23ed, Dreamtech Press

Course Code: PH183	PHYSICS FOR METALLURGISTS	L-T-P: Cr 2-0-2: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Explain the concepts of wave and particle duality of radiant energy.
CO2	Comprehend the concepts of interference, diffraction and polarization.
CO3	Describe the concepts of free electron theory and scattering of electrons.
CO4	Analyze light interference, diffraction and polarization data experimentally.
CO5	Conduct experiments with laser light.
CO6	Conduct experiments using a photodiode.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	1	-	-	-	-	-	-	-	-	-	-	2	-	1	2
CO2	3	1	-	-	-	-	-	-	-	-	-	-	2	-	1	2
CO3	3	1	-	-	-	-	-	-	-	-	-	-	2	-	1	2
CO4	2	-	-	-	3	-	-	-	-	-	-	-	-	-	1	3
CO5	2	-	-	-	3	-	-	-	-	-	-	-	-	-	1	3
CO6	2	-	-	-	3	-	-	-	-	-	-	-	-	-	1	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Wave Optics:

Interference and Diffraction: Concept of interference, Thin film interference, Interferometers. Single, Double and Multiple slit diffraction, Circular aperture, Grating and its application- Spectrometer to determine the wavelength of light source.

Polarization Devices:

Fundamentals, Double refraction, Working and applications of Wave Plates, Half Shade Polarimeter, Polariscope, Isolators.

Quantum Mechanics:

Concepts and Experiments that led to the discovery of Quantum Nature, de-Broglie's matter wave, 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 tunneling.

Free Electron Theory:

Fermi-Dirac statistics, Free Electron Fermi gas-1D, Models of wave mechanics, Applications of Free electron theory, Simple theory of brillouin Zones, Insulators, Semi-conductors, and Metals.

Scattering Phenomena:

Waves and scattering, Coherent and incoherent scattering, Elastic and Inelastic scattering, scattering cross sections, Electrodynamics of X-Ray scattering, Inelastic Compton scattering, Born approximation of coherent elastic scattering for electrons, Scattering of electrons by Model Potentials.

Dielectric Materials: (Introduction to Dielectrics, Dielectric constant – Polarizability - Properties and types of insulating materials - Polarization mechanisms in dielectrics (Qualitative) – Frequency and temperature dependence of polarization – Dielectric loss Clausius-Mossotti Equation (Qualitative)– Piezoelectricity, dielectric Breakdown, Applications.

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.

Learning Resources:

Text Books:

1. Fundamentals of Physics by Halliday, Resnik 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.Physics Laboratory Manual by Physics Department, NIT Warangal,2021.
4.Practical Physics by P.R. Sasi Kumar, PHI publications, first edition,2011

Reference Books:

1.Atomic Theory for Students of Metallurgy by Hume-Rothery W, IOM Communications Ltd, 1988.
2. Solid State Physics by AJ Dekker, , Mcmillan,4th edition, 2000
3.Introduction to Solid State Physics by Charles Kittel, , Wiley Publications,8th Edition, 2005.
4.Engineering Physics Practical by Dr.S.K.Gupta Krishna Prakashan Publications, ninth edition,2010

Online Resources:

1. https://swayam.gov.in/explorer
2. http://vlabs.iitkgp.ac.in/vlt/project.html
3.https://nptel.ac.in/courses/115/105/115105110
4.Amrita virtual labs.

Course Code: MM151	MINERAL PROCESSING	L-T-P: Cr 2-0-0: 2

Pre-Requisites: None

Course Outcomes:

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

CO1	Appreciate the significance and scope of mineral processing in extractive metallurgy
CO2	Choose the right equipment for effective and economical mineral processing at large scale
CO3	Develop a suitable mineral processing flowsheet for a given ore
CO4	Apply the mineral processing principles for upgradation of lean ores

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Unit I: 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.

Unit III: 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.

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

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

Unit VI: 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, high tension separator.

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.

Online Resources:

https://nptel.ac.in/courses/105/105/105105171/

Course Code: CS181	PROBLEM SOLVING AND COMPUTER PROGRAMMING	L-T-P: Cr 3-0-2: 4

Pre-Requisites: None

Course Outcomes:

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

CO1	Design algorithms for solving simple mathematical problems including computing, searching and sorting.
CO2	Compare algorithms in terms of space and time complexity to solve simple mathematical problems.
CO3	Explore the internals of computing systems to suitably develop efficient algorithms.
CO4	Examine the suitability of data types and structures to solve specific problems.
CO5	Apply control structures to develop modular programs to solve mathematical problems.
CO6	Apply object-oriented features in developing programs to solve real world problems.
CO_L1	Develop valid programs to solve mathematical and scientific problems.
CO_L2	Develop and test programs using control structures.
CO_L3	Implement modular programs using functions.
CO_L4	Develop programs using classes.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO6	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_L1	3	-	-	-	3	-	-	-	-	2	-	-	-	-	-	-
CO_L2	3	-	-	-	3	-	-	-	-	2	-	-	-	-	-	-
CO_L3	3	-	-	-	3	-	-	-	-	2	-	-	-	-	-	-
CO_L4	3	-	-	-	3	-	-	-	-	2	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Fundamentals of Computers, Historical perspective, Early 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, Time and space complexities of algorithms.

Number systems and data representation, Basics of C++, Basic data types.

Numbers, Digit separation, Reverse order, Writing in words, Development of Elementary School Arithmetic Testing System, Problems on Date and factorials, Solutions using flow of control constructs, Conditional statements - If-else, Switch-case constructs, Loops - while, do-while, for.

Functions – Modular approach for solving real time problems, user defined functions, library functions, parameter passing - call by value, call by reference, return values, Recursion, Introduction to pointers.

Sorting and searching algorithms, Large integer arithmetic, Single and Multi-Dimensional Arrays, passing arrays as parameters to functions

Magic square and matrix operations using Pointers and Dynamic Arrays, Multidimensional Dynamic Arrays

String processing, File operations.

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

Lab Part-Syllabus:

Laboratory:

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.

Text Books / Reference Books / Online Resources:

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.

Course Code: ME134	WORKSHOP PRACTICE	L-T-P: Cr 0-1-2: 2

Pre-Requisites: None

Course Outcomes:

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

CO1	Demonstrate the operation of engineering workshop tools.
CO2	Manufacture components using workshop trades including fitting, sheet metal, carpentry, foundry and welding
CO3	Perform machining processes including facing, turning, taper turning, grooving, chamfering, thread cutting, knurling and tapping.
CO4	Apply basic electrical engineering knowledge for house wiring practice

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Demonstration of 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.
Plumbing: Demonstration and practice of Plumbing tools, Preparation of Pipe joints with coupling for same diameter and with reducer for different diameters.
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 (Solid / Split Patterns). Demonstration of Sweep Moulding Process.
Welding Shop: Demonstration and practice on Arc Welding and Gas welding. Preparation of Lap joint and Butt joint.
Sheet metal: Demonstration of & Practice on sheet metal tools. Practice on preparing required shapes from a sheet using appropriate tools.

Text Books:

1. Felix W.; “Basic Workshop Technology: Manufacturing Process”.
2. Bruce J. Black, “Workshop Processes, Practices and Materials” (5th Edn.), Routledge publishers.
3. B.S. Raghuwanshi, “A Course in Workshop Technology Vol I. & II”. Dhanpath Rai & Co.
4. Steve F Krar et.al, “Technology of Machine Tools”. TMH publishers
5. Ramesh Babu.V., “Engineering Practices Laboratory Manual”, VRB Publishers Private Limited, Chennai, Revised Edition, 2013 – 2014.
6. T. Jeyapoovan, “Engineering Practices Lab Manual” (4th Edn.), , Vikas Pub.
7. John K.C., “Mechanical Workshop Practice”. PHI.

Reference Books:

1. Elements of Workshop Technology, Vol. I by S. K. Hajrachoudhury &Others, Media Promoters and Publishers, Mumbai. 2007, 14th Edition
2. Elements of Workshop Technology, Vol. II by S. K. Hajrachoudhury &Others, Media Promoters and Publishers, Mumbai. 2007, 12th Edition

3. Workshop Practice by H. S. Bawa, Tata-McGraw Hill, 2004.

Online Resources:

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).

II – Year: I – Semester

Course Code: MA235	TRANSFORMS, COMPLEX VARIABLES AND PARTIAL DIFFERENTIAL EQUATIONS	Credits 3-0-0: 3

Pre-Requisites: MA184

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

CO1	Obtain the Fourier series for a given function
CO2	Find the Fourier transform of a function and Z- transform of a sequence
CO3	Determine the solution of a PDE by variable separable method
CO4	Understand and use of complex variables and evaluation of real integrals

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Fourier Series: Expansion of a function in Fourier series for a given range - Half range sine and cosine expansions.

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

Z-transforms: Z- transform and Inverse Z-transforms – Properties – convolution theorem- simple illustrations.

Partial Differential Equations: Method of separation of variables - Solution of one-dimensional wave equation, one dimensional heat conduction equation and two-dimensional steady state heat conduction equation with illustrations.

Complex Variables: Analytic function - Cauchy Riemann equations - Harmonic functions - Conjugate functions - complex integration - line integrals in complex plane - Cauchy's theorem (simple proof only), Cauchy's integral formula - Taylor's and Laurent's series expansions - zeros and singularities - Residues - residue theorem, use of residue theorem to evaluate the real integrals of the type $\int_0^{2\pi} f(Cos\,\theta, Sin\,\theta)\,d\theta$, $\int_{-\infty}^{\infty} f(x)\,dx$, without poles of the real axis

Text Books:

1. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa Pub. House 5ed, 2016.
2. Erwyn Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons 8ed, 2008.

Course Code: MM201	PHYSICAL METALLURGY	Credits 3-0-0: 3

Pre-Requisites: MM101 – Introduction to Material Science and Engineering

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

CO1	Construct phase diagrams based on the given data on binary alloy systems
CO2	Interpret Fe-Fe3C phase diagram and other binary phase diagrams
CO3	Explain theory of diffusion
CO4	Appraise homogeneous and heterogeneous nucleation
CO5	Discuss the microstructural aspects of metals and alloys

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	-	-	-	-	-	-	-	-	-	-	2	-	2
CO2	3	1	1	-	-	-	-	-	-	-	-	-	-	2	-	2
CO3	3	1	-	-	-	-	-	-	-	-	-	-	-	1	-	1
CO4	3	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-
CO5	3	1	1	-	-	-	-	-	-	-	-	-	-	1	-	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Importance of alloying, Constitution of Alloys.

Equilibrium Diagrams: Experimental methods for construction of equilibrium diagrams, Unary phase diagram, Isomorphous systems, Phase rule and its applications, Lever rule and its applications, Equilibrium heating and cooling of an isomorphous alloy, Coring, Miscibility gaps, Eutectic systems, Congruent melting intermediate phases, Eutectoid, Peritectic, Peritectoid, Monotectic and Syntectic reactions. Study of important binary systems of Fe-Fe3C, Cu-Zn, Cu-Sn, Al-Cu and Al-Si, Emphasis on Fe-Fe3C phase diagram, Effect of alloying elements on Fe-Fe3C phase diagram, interpretation of solidification behaviour and microstructure of different alloys belonging to different systems, Ternary isomorphous and simple eutectic diagrams.

Diffusion in Solids: Diffusion mechanisms, Fick's laws of diffusion, Steady state and non-steady state diffusion, Solution to Fick's second law, Diffusion calculations, Kirkendall effect, Darken's equation, Atomic theory of diffusion, Factors that influence diffusion, 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 – construction, principle of image formation, applications and limitations, reflected/transmitted light microscope, Imaging modes – dark field, bright field, Phase contrast and Differential interference contrast microscopy, Specimen preparation for optical microscopy, Grain size measurement methods – ASTM grain size measurement, Linear intercept method, Jeffry's planimetric method, microstructures of pure metals, microstructure of different alloys (both steels and cast irons), Physical metallurgy of non-ferrous alloys Cu-Al, Brass and Bronze.

Text Books:

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

Reference Books:

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

Online Resources:

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

Course Code: MM202	UNIT PROCESSES IN EXTRACTIVE METALLURGY	Credits 3-0-0: 3

Pre-Requisites:

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

CO1	Discuss basic unit processes used for metals extraction.
CO2	Apply Ellingham diagrams and basic thermodynamic principles for extraction of metals
CO3	Summarize unit processes and principles employed in pyro-, hydro- and electro-metallurgy for mineral beneficiation, refinement and metal extraction.
CO4	Explain reaction kinetics, heat & material balance and process flow sheets for the extraction of non-ferrous metals

Course Articulation Matrix:

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

Text Books:

1. Principles of Extractive Metallurgy, 2nd ed., Terkel Rosenqvist, 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

Online Resources:

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

Course Code: MM203	METALLURGICAL THERMODYNAMICS	Credits 2-1-0: 3

Pre-requisite: Basic knowledge on differentiation, partial differentiation and integration

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

CO1	Explain basic concepts of thermodynamic systems, properties and processes.
CO2	Apply laws of thermodynamics for calculation of energy requirements of various chemical reactions/processes.
CO3	Decide feasibility of thermodynamic reactions using thermodynamics potentials.
CO4	Estimate partial molar quantities, thermodynamic properties of solutions and solubility of gases during preparation of solutions.
CO5	Evaluate thermodynamic properties from electrode potentials of various reactions in electro-chemical cells.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	2	1	1	1	-	-	-	-	-	-	-	1	1	-	-
CO2	3	2	1	1	1	-	-	-	-	-	-	-	3	3	-	-
CO3	3	2	1	1	1	-	-	-	-	-	-	-	3	3	-	-
CO4	3	2	1	1	1	-	-	-	-	-	-	-	1	2	-	-
CO5	3	2	1	1	1	-	-	-	-	-	-	-	2	2	-	-

1: Slightly 2: Moderately 3: Substantially

Syllabus:

Introduction; Work, energy, heat, thermodynamic systems and surroundings; Classes of systems, Properties of state functions and path functions; Thermodynamic processes and cycles, Homogeneous and heterogeneous systems; thermodynamic equilibrium; zeroth law of thermodynamics.

I law of thermodynamics, Different types of work, constant volume process; constant pressure process and the enthalpy H; concept of heat capacity, C_p–C_v = R; Reversible adiabatic and isothermal process, Joule-Thompson coefficient and its significance; Thermo-chemistry, Hess's law, Kirchhoff's law, derivation of kirchhoff's equation, general solution of kirchhoff's equation.

II law of thermodynamics, Carnot cycle, Concept of entropy, Entropy changes in gases, Significance of the sign of entropy change, calculation of entropy change from heat capacities; Spontaneous or natural process, Principle of increase in entropy, Combined expression of I and II laws, Relation between C_p and C_v, Thermodynamic equation of state and its applications, Thermoelastic effect.

Free energy functions-derivation of G and A, Significance of the sign of ΔG; The meaning of thermodynamically feasible process, determination of ΔG from thermal data, Useful relations between G and other thermodynamic functions, Gibbs-Helmholtz equation, Maxwell equations.

III law of thermodynamics, deductions from III law Applications of third law.

Derivation of Clausius-Clapeyron equation, Integration of Clausius-Clapeyron equation, Duhring's rule.

Fugacity – definition, fugacity of an ideal gas, fugacity of non-ideal gas; Activity; Equilibrium constant, Numerical calculations involving equilibrium constant; Variation of equilibrium constant with temperature, Integration of free-energy equation, Sigma function.

Application to Phase Diagrams-Gibbs Phase Rule - Concept of chemical potential, Derivation of Gibbs Phase rule, Illustration of Gibbs phase rule for one component and two component systems, Calculation of liquids line for eutectic systems.

Thermodynamics of solutions-Introduction, Concept of partial molar quantities, derivation of Gibbs-Duhem equation, determination of PMQs, Method of determining molar and partial molar quantities

from each other, general interrelation of PMQs for solutions of fixed composition; Free energy of formation of binary solutions, Ideal solutions, Raoult's law, actual solutions, concept of activity coefficienet; Activity of the solute in dilute solutions-Henry's law, Sievert's law, Integration of Gibbs-Duhem equation, Improved integration of G-D equation - The α function, Excess thermodynamic quantities.

Thermodynamics of electro-chemical cells-introduction, galvanic cells, relation between chemical and electrical energy; Standard emf of a cell, reversible electrode potential, Standard electrode potential, sign convention, standard potentials of metals; Application of Gibbs-Helmholtz equation to galvanic cells; Concentration cells, Oxidation-reduction potential; Reference electrodes-hydrogen electrode, calomel electrode, glass electrode, antimony electrode; Decomposition potential, polarization and over voltage, Applications of emf cells.

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

References:

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. Chemical Metallurgy, J. J. Moore, Butterworh- Heinemann, 1994.
4. Problems in Metallurgical Thermodynamics and Kinetics, G. S. Upadhyaya and R. K Dube, Pergamon, NewYork, 1982
5. Thermodynamics- N. A. Gokcen and R. G. Reddy, Plenum Press – New York & London, 1996, Second Edition.

Course Code: MM204	TRANSPORT PHENOMENA	Credits 2-1-0: 3

Pre-Requisites: MA184- Integral Calculus and Laplace Transforms

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

CO1	Discuss transport properties of fluids and solids.
CO2	Apply mass and momentum transfer principles in the extraction and refining of metals.
CO3	Apply the heat transfer principles in furnace design and thermomechanical treatment of materials.
CO4	Calculate material and energy balances in material flow systems.
CO5	Illustrate simultaneous momentum, heat and mass transfer in metallurgical reactions.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO2	3	2	1	-	-	-	-	-	-	-	-	-	3	2	-	-
CO3	3	2	1	-	-	-	-	-	-	-	-	-	2	2	-	-
CO4	3	2	1	-	-	-	-	-	-	-	-	-	2	-	-	-
CO5	3	2	1	-	-	-	-	-	-	-	-	-	3	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Transport phenomena, Units and Dimensional Analysis. Fluid Flow, Properties of fluids, 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, introduction to stage operations. Similarity criteria and introduction to model and pilot plant studies, Similarities of momentum, mass and energy transfer.

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

Reference Books:

1. David R Gaskell, An Introduction to Transport Phenomena in Materials Engineering, Momentum Press, 2013
2. N J Themelis, Transport and Chemical Rate Phenomena, Routledge, 2004
3. R. B. Bird, W.E. Stewart, E.N. Lightfoot, Transport Phenomena, Wiley- India, 201
4. Julian Szekely, Fluid Flow Phenomena in Metals Processing, Academic Press Inc., 1980
5. G. S. Upadhyaya and R. K Dube, Problems in Metallurgical Thermodynamics and Kinetics, Pergamon, NewYork, 1982

Online Resources:

1. https://nptel.ac.in/noc/courses/noc18/SEM1/noc18-me09/
2. https://ocw.mit.edu/courses/materials-science-and-engineering/3-185-transport-phenomena-in-materials-engineering-fall-2003/index.htm

Course Code: EE232	FUNDAMENTALS OF ELECTRICAL ENGINEERING	Credits 3-0-0: 3

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

CO1	Analyze electric and magnetic circuits.
CO2	Identify the type of electrical machines for a given application.
CO3	Explain the ratings of electrical apparatus.
CO4	Identify meters for measuring electrical quantities

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

DC Circuits: Kirchoff'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.

Magnetic Circuits: Fundamentals and solution of Magnetic circuits, Concepts of self and mutual Inductances, Coefficient of coupling.

Single Phase Transformers: Principle of Operation, EMF equation, Phasor diagram, Equivalent circuit, determination of equivalent circuit parameters, calculation of Regulation & Efficiency.

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, Slip-ring Induction motor, Introduction to synchronous machine (qualitative), applications of electrical machines.

Electrical Measuring Instruments: Moving Coil & Moving iron ammeters & voltmeters. Wattmeter, Digital multi meter (qualitative).

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

Text Books:

1. Electrical & Electronic Technology, Edward Hughes, Pearson Education, 2016, 12th Edition.
2. Electrical Engineering Fundamentals, Vincent Del Toro, Pearson Education, 2015, 2nd Edition.
3. Electrical Machinery - Theory, Performance & Applications, P.S. Bimhbra, Khanna Publishers 2014, 7th edition.
4. Basic Electrical Engineering, V N Mittle and Arvind Mittal, Tata McGraw Hill, 2005, 2nd Edition.

Reference Books:

1. Basic Electrical Engineering, U Bakshi & A. Bakshi, Technical Publications, 2019, 2019-Edition.
2. Principals of Electrical & Electronics Engineering, V. K Mehtha, S. Chand Publications, New Delhi, 2010, 3rd Edition.
3. Electrical Machines, A Fitzgerald, Charles Kingsley, Stephen Umans, McGraw Hill Education, 2017, 6th edition.
4. Electric Machinery, Stephen.J.Chapman, McGraw Hill International Edition, 2017, 4th edition.

Online Resources:

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

Course Code: MM205	PHYSICAL METALLURGY AND METALLOGRAPHY LABORATORY	Credits 0-1-2: 2

Pre-Requisites: None

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

CO1	Appraise the atomic packing efficiency, linear and planar densities by constructing crystal structure models.
CO2	Prepare metallic samples for microstructural observation.
CO3	Examine the microstructures of ferrous and non-ferrous alloy samples.
CO4	Distinguish the microstructures of steels and cast irons.
CO5	Determine the grain size and volume fractions of phases in the given microstructure.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	2	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-
CO2	2	-	-	-	2	1	-	-	2	3	-	-	-	2	-	2
CO3	2	1	-	-	2	-	-	-	-	3	-	-	-	2	-	1
CO4	2	1	-	-	2	-	-	-	-	3	-	-	-	2	-	1
CO5	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

Text Books:

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

Reference Books:

1. Metallography and Microstructures, ASM Handbook Volume 9, George F Vander Voort (Ed.), ASM International, 2004
2. Physical Metallurgy for Engineers, D. S. Clark and W. R. Varney, CBS Publications, New Delhi, 1st Edition, 1979.
3. Introduction of Physical Metallurgy, S. H. Avner, Mc Graw Hill, 2nd Edition, 1987.
4. Callister's Materials Science and Engineering, R. Balasubramaniam, Wiley India, 2014, 2ed.

Online Resources:

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

Course Code: MM206	UNIT PROCESSES IN EXTRACTIVE METALLURGY LABORATORY	Credits 0-1-2: 2

Pre-Requisites:

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

CO1	Carry out suitable unit process for extraction of metals
CO2	Perform suitable concentration technique for leach solution
CO3	Carryout electro deposition of metals
CO4	Identify techniques for recovery of metals from leach solutions

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Sampling and Sieve analysis
2. Comminution: Crushing
3. Comminution: Grinding
4. Verification of Stoke's law
5. Calcination
6. Oxidising Roasting
7. Reduction of oxide
8. Cementation
9. Electrolysis to deposit Ni and Cr
10. Effect of cathodic current density and throwing power on electroplating process
11. Leaching of ores
12. Anodising
13. Solvent Extraction

Text Books:

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

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.

Course Code: EE233	BASIC ELECTRICAL ENGINEERING LABORATORY	Credits 0-0-3: 1.5

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

CO1	Select the range of apparatus based on the ratings of DC machines, transformers and
CO2	Verify the operation of KVL, KCL and Superposition theorems applied to simple dc
CO3	Determine equivalent circuit parameters of transformers by conducting OC and SC tests.
CO4	Evaluate the performance of DC machines & its braking methods.
CO5	Evaluate the performance of AC machines and Transformers

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	2	-	-	-	-	2	-	-	-	-	-	-
CO2	3	-	-	-	1	-	-	-	-	2	-	-	-	1	-	-
CO3	3	-	-	-	1	-	-	-	-	2	-	-	-	1	-	-
CO4	3	-	-	-	1	-	-	-	-	2	-	-	-	-	-	-
CO5	3	-	-	-	1	-	-	-	-	2	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Electrical a) Verification of Kirchhoff's Voltage and Current Laws.
2. Verification of Superposition Theorem.
3. Calculation of the Power factor and Power in a Single Phase Series R-L circuit
4. Measurement of Self and Mutual inductance of Coils.
5. No load test on a DC Machine.
6. Load Test on a DC Shunt Generator.
7. Speed Control of a DC Shunt Motor.
8. a) Determination of Equivalent Circuit Parameters of a Single Phase Transformer.
9. b) Predetermination of Efficiency and Regulation of a Single Phase Transformer.
10. Direct Load test on a Single Phase Transformer.
11. Separation of No-load Losses of a Single phase Transformer.
12. Direct Load test on a Three Phase Induction Motor.
13. Measurement of resistance and resistivity.

Manual/ Text Books:

1. Manual for Basic Electrical Engineering Laboratory
2. Basic Electrical Engineering Theory

Reference Books:

1. Basic Electrical Engineering, U Bakshi & A. Bakshi, Technical Publications, 2019, 2019-Edition.
2. Principals of Electrical & Electronics Engineering, V. K Mehtha, S. Chand Publications, New Delhi, 2010, 3rd Edition.

Online Resources:
https://nptel.ac.in/courses/108/108/108108076/

II – Year: II – Semester

Course Code: MA285	STATISTICS AND NUMERICAL METHODS	Credits 2-0-0: 2

Pre-requisites: MA235- Transforms, Complex Variables and Partial Differential Equations

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

CO1	Understand the concepts of probability and statistics
CO2	Perform testing of hypothesis
CO3	Interpret an experimental data using interpolation / curve fitting
CO4	Solve algebraic/transcendental equations and ordinary differential equations numerically

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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, single proportion and difference of proportions - t-test for single mean and difference of means - F-test for comparison of variances, Chi-square test for goodness of fit - Karl Pearson coefficient of correlation, lines of regression and examples, ANOVA

Numerical Methods: Curve fitting by the method of least squares. Fitting of (i) Straight line (ii) Second degree parabola (iii) Exponential curves - 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, modified Euler's method, 4th order Runge-Kutta method for solving first order ordinary differential equations

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, Eighth Edition

Reference Books:

1. Miller & Freund's Probability and Statistics for Engineers, **Richard A. Johnson**, Pearson, 2018, Ninth Edition
2. Higher Engineering Mathematics, **B. S. Grewal**, Khanna Publishers, 2012, 42nd Edition

Course Code: MM251	PHASE TRASFORMATIONS AND HEAT TREATMENT	Credits 3-0-0: 3

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

CO1	Explain the concepts of phase transformations in metals and alloys.
CO2	Apply TTT and CCT diagrams to interpret microstructural development in steels.
CO3	Discuss industrial heat treatment techniques to engineer microstructure for optimization of mechanical properties in metals and alloys.
CO4	Apply surface modification concepts for betterment of industrial components

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

PHASE TRANSFORMATION: Phase Transformation 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, Transformation of Austenite on Continuous cooling, Effect of Alloying on TTT/ CCT Curves.

PRINCIPLES OF HEAT TREATMENT: Annealing, Normalising, Hardening and Tempering of Steels, Hardening Defects, Transformation in Tempering, Temper Embrittlement, Subzero treatment, Mechanism of heat removal during Quenching, Quenching Media, Residual Stress and Quench Cracks, Martempering, Austempering, Hardenability and its Measurement, Effect of alloying on Hardenability.

HEAT TREATMENT OF ALLOY STEELS: Classification of Alloy Steels, Advantage and Disadvantage of Alloy Steel, Types of Alloy Steels, Heat Treatment of HSLA, Tool Steels, Hadfield Mn Steel, Stainless Steel

HEAT TREATMENT OF CAST IRONS: Structure-Property Correlation of different Cast Irons, Manufacturing of Cast Irons, Heat Treatment of Cast Irons – Malleabilisation, Austemper Ductile Irons, Application of Alloy Cast Irons.

AGE HARDENING: Concept of Age Hardening, Steps of Age Hardening, Application of Age Hardening, Study of Age Hardened Alloys (ferrous/ nonferrous).

CASE HARDENING AND SURFACE TREATMENT: Carburising, Nitriding, Boronizing, Carbonitriding, Case Depth Measurement of Case-Hardened Alloys, Frame, Induction and Laser Hardening of Alloys, Industrial Heat Treatment Practice, Case Study.

Pollution & Quality Control in HT Industry: Generation and remedies of Pollution and Statistical Quality control in HT Industry, Quality Management policy

Text Books:

1. Phase Transformation in Metals and Alloys, VNR International, 1992 – D. A. Porter and K. E. Easterling.
2. Engineering Physical Metallurgy, Mir Publishers, 1997 – Y. Lakhtin.

Reference Books:

1. Phase Transformation, Prentice Hall of India, 1992 – V. Raghavan.
2. Introduction to Physical Metallurgy, Tata McGraw-Hill Publisher, 1997, S. H. Avner.

Course Code: MM252	SOLIDIFICATION PROCESSING	Credits 3-0-0: 3

Pre-requisites:

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

CO1	Explain the principles of solidification in metals and alloys
CO2	Correlate the morpho-genesis of solidification microstructures with the heat and mass transfer conditions
CO3	Describe the casting techniques
CO4	Design the gating and risering of castings
CO5	Identify the melting furnaces for metals and alloys

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO4	3	2	2	2	-	-	-	-	-	-	-	-	3	-	-	1
CO5	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, Microsegregation, Constitutional undercooling, Theories of nucleation and growth: Mullins-Sekerka instability, Ivantsov's 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, Types of casting, Heat transfer, design of riser and gating. Solidification, heat transfer, fluid flow during fusion welding. Casting Defects. Melting furnaces. Melting and solidification of cast irons and aluminium. Solidification, heat transfer and fluid flow during fusion welding.

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.

Course Code: MM253	IRON MAKING TECHNOLOGY	Credits 3-0-0: 3

Pre-Requisites:

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

CO1	Explain raw materials and basic principles of iron making.
CO2	Discuss the extraction technique of pig iron using blast furnace from iron ores.
CO3	Describe the physico-chemical processes occurring in a blast furnace
CO4	Compare alternate routes of iron making.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

History of Ironmaking: Importance of Iron and Steel for the modern society, Introduction to pig iron production India and the world, Developments that led to modern ironmaking.

Preparation of burden materials: Introduction, Iron ore deposits in India and the world. Metallurgical coal, Limestone and Dolomite, Coke: functions, quality requirements such as reactivity, size, strength and abrasion resistance, coke reactivity test and coke strength after reaction. Sintering: principle, process variables, and mechanism of sintering, recent trends in sintering practice. Pelletization: principle, theory of bonding, mechanism of ball formation, disc pelletizer, drum pelletizer, induration of pellets, process variables in pelletization, recent trends in pelletization process, Nodulization, Testing of Burden materials

Blast Furnace principles and operation: Introduction, construction of blast furnace and its accessories such as blast furnace stoves and gas cleaning system. Thermal, physical and chemical profiles, equilibria in C-O, Fe-C-O, Fe-O-H systems, kinetics of iron oxide reduction. Reactions at various zones: stack, bosh, belly, tuyere and hearth zones. Operational procedures in blast furnace: drying, filling, lighting, banking, blowing out, tapping, fanning, back drafting. Irregulaties in blast furnace: hanging, scaffolding, slip, chilled hearth, pillaring, breakout, choking of gas offtake, flooding and coke ejection, channelling and salamander formation. Impact of burden distribution on the blast furnace performance. Modern trends in Blast furnace design and practice: Large-capacity blast furnaces, modifications in top charging system, stock line armour and high top pressure.

Alternate routes of iron production: Low shaft furnace, mini-blast furnaces, submerged arc furnace. Sponge iron production: Rotary kiln process, rotary hearth furnace based processes, HYL processes, Midrex process, fluidized bed processes. Uses of sponge iron. Smelting reduction processes: fundamentals, Elred process, Inred process, Corex process, Finex process, Fastmelt process, Hismelt process, Cleansmelt process, Cyclone converter furnace process, Plasmasmelt process.

Text Books:

1. R.H. Tupkary, V.R. Tupkary, Modern Iron making handbook, MLI Handbook Series, 2017.
2. C. Bodsworth, Physical Chemistry of Iron and Steel manufacture, Metallurgy and Metallurgical Engineering Series, 2014.
3. David H. Wakelin, Richard J. Fruehan, The making, shaping and treating of steel: Iron making volume, 11th edition, AISE steel foundation, 1999.
4. Amit Chatterjee, Sponge iron production by direct reduction of iron oxide, PHI learning private limited, 2010.
5. Arabinda Sarangi, Bidyapati Sarangi, Sponge iron production by rotary kiln, PHI learning private limited, 2011.
6. Amit Chatterjee, Hot metal production by smelting reduction of iron oxide, PHI learning private limited, 2010.

Reference Books:

1. F. Habashi, Principles of Extractive Metallurgy, Vol. 1-4, McGraw-Hill, 1993.
2. M. Shamsuddin, Physical Chemistry of Metallurgical Processes, Wiley, 2016.

Course Code: MM254	ELECTRONIC AND MAGNETIC MATERIALS	Credits 3-0-0: 3

Pre-Requisites: PH183- Engineering Physics

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

CO1	Explain the electronic principles of magnetics, semiconductors, and superconductors
CO2	Design microstructures for enhanced magnetic properties of materials
CO3	Describe the structure and industrial processing of semiconducting materials
CO4	Discuss the structure and synthesis of superconducting materials

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Magnetic Materials:

Brief introduction: Origin of magnetism, Permanent magnetic moments of atoms, Magnetic domains, Superparamagnetism, Types of magnetic materials, Soft and hard magnetic materials; Ferrites-classification and crystal structure, Nanocrystalline soft magnetic materials, Melt-quenching method for soft magnetic ribbons and metallic glasses; Permanent magnets - properties and preparation of sintered magnets, high performance rare-earth permanent magnets (NdFeB & SmCo)

Semiconducting Materials:

Brief introduction to semiconductor principles: band diagrams, doping, carrier concentration, I-V characteristics; Manufacturing of metallurgical grade silicon, Siemens process for electronic grade Si, Growth of single crystals by Czochralski process, Silicon wafer preparation for electronic devices. Techniques involved in preparation of electronic chips: Lithography, physical and chemical vapour deposition.

Solar cells: Photovoltaic effect, Types of silicon solar cells (singlecrystal, polycrystalline, & amorphous), Fabrication and functioning of silicon solar cells, Multi-junction solar cells

Superconducting Materials:

Temperature dependence of resistance, BCS theory, Type I and II superconductors, Meissner-Effect, High temperature Superconductors, YBCO & Bi-2212 – Crystal structure, Applications, Persistent current, Levitation; Synthesis of YBCO superconductors

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.
3. Lecture Notes

Online Resources:

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

Course Code: CH281	POLYMER TECHNOLOGY	Credits 3-0-0: 3

Pre-Requisites: None

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

CO1	Describe thermodynamics of polymer structures
CO2	Select polymerization reactor for a polymer product
CO3	Characterize polymers.
CO4	State polymer additives, blends and composites.
CO5	Explain polymer rheology.
CO6	Identify suitable polymer processing methods

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	1	-	-	-	-	-	-	-	-	3	2	1	-
CO2	2	2	3	1	-	-	-	-	-	-	-	-	2	3	1	-
CO3	2	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO4	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO5	2	-	2	-	-	-	-	-	-	-	-	-	2	-	-	-
CO6	2	2	1	2	-	-	-	-	-	-	-	-	2	2	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction and Classification of Polymers. Thermosets, Factors influencing the polymer properties, Monomers used for polymer synthesis, synthesis procedure for monomers Styrene, ethylene, Vinyl monomers etc., Thermoplastics, Linear Branch, Cross Linked Polymers, Ewart Kinetics for emulsion polymerization.

Addition polymers – kinetics, synthesis and reactions, Condensation polymers, Kinetics reaction and processes, Polymerization Techniques - Emulsion polymerization and Suspension polymerization, Interfacial Polymerization with their merits

Molecular Weights, Polydispersity Index, Different Methods of determination of Molecular weight, Effect of Molecular weight on Engineering Properties of Polymers, Smith Ewart Kinetics for emulsion polymerization, Kinetics of free radical polymerization, Chain transfer agents, Kinetics of Step growth polymerization, Ziegler Natta polymerization Processes, Differentiation based on kinetics of Anionic and cationic polymers

Polymerization reactors types and mode of operation, Polymerization reactor design, control of polymerization, Post polymerization unit operations and unit processes

High Performance and Specialty Polymers, Polymer additives, compounding. Fillers, plasticizers, lubricants, colorants, UV stabilizers, fire retardants and antioxidants.

Impact, flexural tensile testing methods of polymers, Mechanical Properties of Polymers, Thermodynamics of Polymer Mixtures, ASTM and ISO methods for testing of polymers.

Polymer processing: Extrusion process, Twin and Single Screw extrusion, Blow moulding, injection moulding, Wet and Dry spinning processes, thermo set moulding. Processing of polymer nanocomposites.

Manufacturing of polymers: flow-sheet diagrams, properties & applications of PE, PP, PS, Polyesters, Nylons, ABS and PC.

Text Books:

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

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.

Online Resources:

NPTEL Lecture: https://nptel.ac.in/courses/103/106/105106205/
NPTEL Lecture: https://nptel.ac.in/courses/103/107/103107139/

Course Code: MM255	PHASE TRANSFORMATIONS AND HEAT TREATMENT LABORATORY	Credits 0-1-2: 2

Pre-requisite: Physical Metallurgy

Course Outcome: At the end of the semester, the student will be exposed to

CO1	Practice industrial heat treatment processes for ferrous and nonferrous alloys.
CO2	Observe microstructure using optical and scanning electron microscopes.
CO3	Evaluate the hardenability of steels by Jominy end quench test.
CO4	Conduct microstructure-property correlation of heat treated samples

Course Articulation Matrix:

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

Experiment Details:

1	Grain size measurement & Calculation of Volume fraction of Phases of given Microstructure by Line Intercept method
2	Grain size Measurement by American Society for Testing and Materials (ASTM) Method
3	Observation of Microstructure of various Steels and Composite Materials
4	Microstructure Study of Annealing & Normalized Samples
5	Microstructure Study of Hardened Samples
6	Tempering of Hardened Steel Samples and Study the effect of Tempering Condition on the Hardness of Samples
7	Determination of Hardenability by Jominy End Quench Test (Demonstration)
8	Scanning Electron Microscopy (SEM) Study of Different Samples

Text Books:

1. Introduction of Physical Metallurgy, Mc Graw Hill, 1987- S. H. Avner.
2. Alloy Phase Diagrams, ASM Handbook, Volume 3.

Course Code: MM256	SOLIDIFICATION PROCESSING LABORATORY	Credits 0-1-2: 2

Pre-requisites: None

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

CO1	Determine moulding sand properties.
CO2	Demonstrate the preparation of moulds
CO3	Demonstrate melting practice
CO4	Demonstrate casting of metals/alloys.

Course Articulation Matrix:

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

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.

Course Code: EC283	BASIC ELECTRONICS LABORATORY	Credits 0-0-3: 1.5

Pre-requisites: None

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

CO1	Develop and employ circuit models for elementary electronic components using diodes, transistors, and operational amplifier.
CO2	Design simple circuits containing non-linear elements (transistors) using the concepts of load lines, operating points and incremental analysis.
CO3	Calculate frequency response curves of single stage BJT amplifier and determine bandwidth of the amplifier.
CO4	Demonstrate binary functions electronically using Diodes, BJTs and JFET's.
CO5	Build and troubleshoot simple electronic analog and digital circuits.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	3	-	1	-	-	2	-	-	-	-	-	2
CO2	3	-	-	-	3	-	-	-	-	2	-	-	-	-	-	2
CO3	3	-	-	-	3	-	-	-	-	2	-	-	-	-	-	2
CO4	3	-	-	-	3	-	-	-	-	2	-	-	-	-	-	2
CO5	3	-	-	-	3	-	-	-	-	2	-	-	-	-	-	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Characteristics of PN junction Diode
2. Load regulation characteristics of Zener diode
3. Rectifiers & Filters.
4. Characteristics of BJT
5. Characteristics of JFET
6. Single stage Amplifier.
7. R.C. Phase shift oscillator.
8. Clippers and Clampers.
9. Op-amp Frequency Response
10. Verification of Logic Gates.

Reference Books:

Basic Electronics Laboratory Manual

III – Year: I – Semester

Course Code: SM335	BUSINESS ECONOMICS AND FINANCE FOR ENGINEERS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Apply micro economic principles for effective resource utilization
CO2	Describe business and economic environments at national and international levels
CO3	Analyse the financial statements of a company
CO4	Apply cost concepts to control costs at operational level.
CO5	Develop effective presentation skills with special emphasis on contemporary topics

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	-	-	2	-	-	-	-	-	-	-	3	-	1	-	-	-
CO2	-	-	2	-	-	-	-	-	-	-	3	-	1	-	-	-
CO3	-	2	2	-	-	-	-	1	-	-	3	-	1	-	-	-
CO4	-	2	2	-	-	-	-	-	-	-	3	-	1	-	-	-
CO5	-	-	2	-	-	-	-	-	-	3	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Chapter – 1 Introduction to micro economic concepts. Demand and supply factors, equilibrium and price determination, different factors affecting the demand and supply. Types of market and its influence on price and equilibrium.

Chapter – 2 Introduction to National Income National Income- Definition, Circular flow, various concepts and methods of estimation, limitations and advantages.

Chapter - 3 Inflation: Inflation – Meaning, CPI and WPI, Theories of inflation and measures to control inflation.

Chapter – 4- Balance of Payments Balance of Payments, Definition, Imbalances in BOP and Policies for correction in imbalances, Foreign exchange determination.

Chapter – 5 Economic Policy of 1991- Economic policy of 1991-Introduction and changes in various economic policies by the Central Government (Current Affairs).

Chapter – 6 Financial Statements Financial statements- Income statement and Balance sheet - Analysis (Simple ratios).

Chapter – 7 Methods of Economic Analysis Capital budgeting techniques – Time value of money – Various methods of economic analysis (Pay back, ARR, NPV, IRR and benefit cost ratio).

Chapter – 8 Application of cost concepts. Cost concepts – Breakeven Analysis, Meaning and its application and Limitations. Preparation of cost sheet,

Presentations / Group discussions on current topics

Text Books:

1. D N Dwivedi “Managerial Economics”, Vikas Publishing House Private Limited
2. Agrawal AN, “Indian Economy” Wiley Eastern Ltd, New Delhi
3. R.K Sharma and Sashi K Gupta,” Financial Management”, Kalyani Publications
4. Arora, M.N.” Cost Accounting”, Vikas Publication.

Online Resources:

1. Latest trends in Indian Economy.
2. Capitaline Plus Database – http://www.capitaline.com/
3. Ministry of Finance – http:/finmin.nic.in/
4. Database of Indian Economy - http://dbie.rbi.org.in
5. Statistics of India – http://statistics of india.com/ or www.indiastat.com/ or http://mospi.nic.in/
6. The Economist Magazine.

Course Code: MM301	STEEL MAKING TECHNOLOGY	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Explain basic principles of steel making
CO2	Differentiate open hearth, Bessemer, LD and Q-BOP steel making processes
CO3	Describe the secondary refining techniques of steel making
CO4	Discuss the practice of the continuous casting of steel

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: History of steelmaking in India and the world, thermodynamics and kinetics in steelmaking.

Conventional steelmaking practices: Bessemer process and open-hearth process.

Modern steelmaking practices: Basic oxygen steelmaking processes: LD process, OBM process, Rotating BOF processes and hybrid processes; steelmaking by electric arc furnace and induction melting processes

Secondary steelmaking processes: Deoxidation process, ladle metallurgy, injection metallurgy, AOD, VOD, CLU, MRP, SR-KCB processes, VAR & ESR processes. Tundish metallurgy, ingot casting process, and continuous casting process

Text Books:

1. Beyond the Blast Furnace, Amit Chatterjee, CRC Press, 1992.
2. Sponge Iron Production in Rotary Kiln, Arabinda Sarangi, Bidyapati Sarangi, PHI learning pvt. Ltd., New Delhi, 2011.
3. Hot Metal Production by Smelting Reduction of Iron Oxides, Amit Chatterjee, PHI Learning Pvt. Ltd., NewDlehi, 2010.
4. Iron Making and Steel Making- Theory and Practice, Ahindra Ghosh and Amit Chatterjee, Prentice-Hall of India Pvt. Ltd, 2008.
5. Steel Making, A. K. Chakrabarti, PHI Learning Pvt. Ltd., NewDlehi, 2007.
6. Secondary Steel Making- Principles and Applications, Ahindra Ghosh, CRC Press, 2001.

Online Resources:

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

Course Code: MM302	MECHANICAL BEHAVIOUR OF MATERIALS	Credits 3-0-0: 3

Pre-Requisites: MM201-Physical Metallurgy

Course Outcomes:

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

CO1	Explain the theories of elastic and plastic behaviour of materials
CO2	Describe the effect of dislocations on materials properties
CO3	Discuss the strengthening mechanisms of materials
CO4	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
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO3	3	-	1	-	-	-	-	-	-	-	-	-	-	2	-	-
CO4	3	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

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, Forces between Dislocations, dislocation and plastic strain, Dissociation or Combination of Dislocations, Dissociation Criterion, Glide plane of dislocation, Dislocation-Precipitate Interactions, Frank-Read Source: Dislocation Multiplication, Dislocation Pileups.

Strengthening Mechanisms: Types of strengthening mechanisms, Grain boundary strengthening, Hall-Petch Relation, Hall-Petch strengthening limit, Strengthening from second phase, Factors influencing second-phase particle strengthening, Solid Solutions strengthening, Precipitation Hardening, Precipitation Sequence-GP Zones, Factors affecting precipitation hardening, Interaction between particles and dislocations-Particle Cutting and Orowan mechanism, Coherent and Incoherent Precipitates, 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 and properties derived from it, Elastic strain recovery, Instability in tension, necking criterion, Yield Point Phenomenon, Strain Aging, Dynamic strain ageing, 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.

Text Books:

1. George E. Dieter, Mechanical Metallurgy, McGraw Hill, New York, 3rd Edition, 1986. (ISBN 0-07-016853-8) TA405.D53

2. Norman E. Dowling, Mechanical Behavior of Materials, Prentice-Hall, Upper Saddle River, New Jersey, 2nd Edition, 1999. (ISBN0-13-905720-X)
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.

Course Code: MM303	POWDER METALLURGY	Credits 3-0-0: 3

Pre-Requisites: None

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

CO1	Explain powder production technique
CO2	Describe the characterization techniques of the metal powders
CO3	Discuss powder shaping techniques
CO4	Explain the stages of sintering and influence of sintering atmospheres
CO5	Discuss case studies on processing of industrial components

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	2	-	1	-
CO2	3	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
CO3	3	-	-	-	-	-	-	-	-	-	-	-	3	-	1	-
CO4	3	2	2	-	-	-	-	-	-	-	-	-	3	2	-	-
CO5	3	-	-	3	-	-	-	-	-	3	-	3	2	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

General Concepts:

Introduction and History of Powder Metallurgy (PM), Present and Future Trends of PM

Powder Production Techniques:

Different Mechanical and Chemical methods, Application of Mechanical Alloying, Atomisation of Powder, other emerging processes, Performance Evaluation of different Processes, Design & Selection of Process.

Characterization Techniques: Particle Size & Shape Distribution, Electron Microscopy of Powder, Interparticle Friction, Compression ability, Powder Structure, Chemical Characterization.

Microstructure Control of Powder: Importance of Microstructure Study, Microstructures of Powder by Different techniques.

Powder Shaping: Particle Packing Modifications, Lubricants & Binders, Powder Compaction & Process Variables, Pressure & Density Distribution during Compaction, Isostatic Pressing, Injection Molding, Powder Extrusion, Slip Casting, Tape Casting, Analysis of Defects of Powder Compact, 3D Printers for Ceramics.

Sintering: Theory of Sintering, Sintering of Single & Mixed Phase Powder, Liquid Phase Sintering, Sintering Variables, Modern Sintering Techniques, Physical & Mechanical Properties Evaluation, Structure-Property Correlation Study, Modern Sintering Techniques, Laser Engineering Net Shaping (LENS), Defects Analysis of Sintered Components.

Application of Powder Metallurgy: Filters, Tungsten Filaments, Self-Lubricating Bearings, Porous Materials, ODS Alloys, Biomaterials and Case Study.

Text Books:

1. Powder Metallurgy & Particulate Materials Processing, R. M. German, MPIF, 2005, USA.
    a. Upadhyaya and G S Upadhyaya, Powder Metallurgy, Universities Press, Hyderabad,
2. India, 1st Edition, 2011.
3. J. S. Hirschhorn: Introduction to Powder Metallurgy, American Powder Metallurgy Institute,
4. Princeton, NJ, 1976.
5. P. C. Angelo and R. Subramanian: Powder Metallurgy- Science, Technology and Applications,
6. PHI, New Delhi, 2008.

Course Code: MM304	MECHANICAL BEHAVIOUR OF MATERIALS LABORATORY	Credits 0-1-2: 2

Pre-Requisites: None

Course Outcomes:

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

CO1	Operate testing equipment for measuring mechanical properties
CO2	Analyse the data from mechanical testing.
CO3	Suggest suitable equipment for determination of mechanical properties of bulk and sheet metal products
CO4	Communicate results in the form a report

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Determination of Vickers, Brinell and Rockwell hardness;
2. Poldi impact hardness; Shore Scleroscope hardness;
3. Determination of n and k of given materials;
4. Erichsen Ductility test,
5. Standard impact tests: Charpy and Izod Test;
6. Tensile/ Compression Test;
7. Wear Test.

Text Books/Readings:

1. Mechanical Behavior of Materials Laboratory Manual
2. ASM Metals Handbook, Vol 08 - Mechanical Testing and Evaluation
3. Hardness Testing Principles and Applications-ASM International (2011), Konrad Herrman

Course Code: MM305	POWDER METALLURGY LABORATORY	Credits 0-1-2: 2

Pre-requisites: None

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

CO1	Synthesize metallic and ceramic powders
CO2	Determine the characteristics of powders
CO3	Determine physical characteristics of green compact
CO4	Evaluate the physical and mechanical properties of sintered compacts

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

TEXT BOOKS:

1. Sintering Theory and Practice, R. M. German, New York, Wiley-VCH 1996
2. ASM Hand Book, ASM International, Vol: 7: Powder Metallurgy.

Course Code: MM311	PHYSICAL METALLURGY OF NON-FERROUS METALS AND ALLOYS	Credits 3-0-0: 3

Pre-Requisites: MM201- Physical Metallurgy

Course Outcomes:

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

CO1	Explain the structure-property correlations in non-ferrous metals and alloys.
CO2	Analyse the phase diagrams of non-ferrous alloys
CO3	Explain the heat treatment techniques applied to non-ferrous systems
CO4	Select a non-ferrous alloy for a specific application

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

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

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

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

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

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

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

Lead, Zinc and Tin and their alloys: Compositions, heat treatments, properties and applications.

Babbitts (Antifriction alloys): Compositions, heat treatments, properties and applications.

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

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

Text Books:

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

Reference Books:

3. Metals Handbook–Vol.2: Properties and Selection- Non-ferrous alloys and Pure Metals, ASM, 2014.

4. Charlie R Books, Heat Treatment- Structure and Properties of Non-ferrous Alloys, ASM,1982.

Online Resources:

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

Course Code: MM312	FUELS AND REFRACTORIES	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Describe the production of solid, liquid and gaseous fuels.
CO2	Classify the fuels and refractories specific to their operating conditions.
CO3	Choose the optimum combination of fuels, and refractories to minimize the overall cost
CO4	Illustrate the composition, properties, testing and applications of fuels and refractories.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Solid fuels: Origin of coals – types – properties – storage and pulverization of coal. Coke making by Beehive and byproduct coke ovens. Testing of coke, properties of coke for Blast furnace operation.
Liquid fuels: Principles of Crude petroleum refining, cracking.
Gaseous fuels: Manufacture, properties and uses of producer gas, water gas, coke oven gas and Blast furnace gas.
Comparison of Fuels: Solid, liquid and gaseous fuels
Refractories: Classification of refractories, production, composition, properties, testing and application of common refractories such as Silica, Fire clay, Magnesite, Chrome and Dolomite refractories, Special 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.

Text Books:

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

Reference Books:

1. W. Trinks and M. H. Mawhinney, Industrial Furnaces, John Wiley and Sons, 6th Edition, 2003.

Online Resources:

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

Course Code: MM313	MATERIALS FOR BIO-APPLICATIONS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Identify materials requirements for bio-applications.
CO2	Classify biomaterials.
CO3	Assess a material for bioapplications
CO4	Conduct case studies on materials selection for bio-applications

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Overview of biomaterials: Historical developments, impact of materials.

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

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

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

Text Books:

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

Reference Books:

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

Online Resources:

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

Course Code: MM314	SMART MATERIALS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Classify smart materials based on the general operational principles.
CO2	Describe the principles and applications of piezoelectric and magnetostrictive materials.
CO3	Discuss the mechanism of shape memory, self-healing and self-organizing materials.
CO4	Select materials for thermo-chromic and photo-chromic applications.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Overview of Smart Materials: Introduction and definition of Smart Materials, Principles of smart materials, input – output decision ability, Devices based on conductivity changes, Devices based on changes in optical response, Biological systems and smart materials, Devices based on magnetization, Artificial structures, surfaces, hetero structures, polycrystalline, amorphous, liquid crystalline materials. Piezoelectricty and Magnetostriction: Principles of Piezoelectricty, Perovskyte Piezoceramic Materials, Single Crystals vs Polycrystalline Systems, Piezoelectric Polymers, Principles of Magnetostriction, Rare earth Magnetostrictive materials, Giant Magnetostriction and Magneto resistance Effect, Magnetorheological fluids, Electrorheological materials and their applications.

Electro-active Materials: Electronic Materials, Electro-active Polymers, Ionic Polymer Matrix Composites (IPMC)

Shape Memory Alloys: Shape Memory Effect, Shape Memory Alloys, Shape Memory Polymers, Self-Sensing Piezoelectric Transducers, Energy Harvesting Materials, Self-healing materials. Micro-electro mechanical Smart Systems, Intelligent devices based on smart materials, Self-organizing nano materials Smart materials in drug delivery, Thermo-chromic and photo-chromic applications and hybrid and composite systems, Green materials and Energy materials.

Text Books:

1. Smart materials and new technologies, M. Addington, Schodek, L. Daniel, Architectural Press, 2005.
2. Smart Materials and Structures, M.V. Gandhi, B.S. Thompson, Chapman & Hall, 1992.
3. Smart Structures and Materials, B. Culshaw, Artech House, 2000.
4. Shape Memory Materials, D.I. Arun, P. Chakravarthy, R. Arockia Kumar, B. Santhosh, CRC Press, 2018.

Reference Books:

1. Smart Materials: Proceedings of the 1st Caesarium, Hoffmann, Karl-Heinz (Ed.), Springer, 1999.
2. Smart Materials – An Industrial Perspective, P. Nikhil Chandra, Mothi Krishna Mohan, Notion Press, 2021.
3. Encyclopedia of Smart Materials, Volumes 1-2, M. Schwartz, Willey, 2002.
4. Smart material systems, Smith C, Ralph, SIAM, 2005.
5. Smart Structures: Physical Behaviour, Mathematical Modelling and Applications, P. Gauenzi, Wiley Publishers, 2009.
6. Smart Material Systems and MEMS: Design and Development Methodologies, V. K. Varadan, K. J. Vinoy, S. Gopalakrishnan, John Wiley and Sons, 2006.

Online Resources:

1. https://nptel.ac.in/courses/112/104/112104251/

2. https://nptel.ac.in/courses/113/105/113105081/

Course Code: MM315	ADVANCED METALLURGICAL THERMODYNAMICS	Credits 3-0-0: 3

Pre-requisite: MM203: Metallurgical Thermodynamics

Course Outcomes:

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

CO1	Apply thermodynamic concepts in studying the phase diagrams
CO2	Identify the importance of thermodynamics in solid state solutions
CO3	Assess the role of thermodynamics in phase transformations
CO4	Explain thermodynamics for heterogeneous systems

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Basics: First, second and third laws of thermodynamics, thermodynamic potentials, Maxwell's relations, Clausius-Clayperon 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, Eutectioid reaction, Bainitic transformation, Kinetics of eutectoid transformations, Martensitic Transformation.

Heterogeneous Systems: Equilibrium constant, Ellingham diagrams and their application to commercially important reactions.

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.
4. Principles of Extractive Metallurgy, H.S. Ray.

Reference books:

1. Textbook of Materials and Metallurgical Thermodynamics, Ahindra Ghosh, Prentice Hall of India Pvt. Ltd., 2003.
2. Introduction to Metallurgical Thermodynamics, D.R. Gaskell.
3. Introduction to the Thermodynamics of Materials, David R. Gaskell and David E. Laughlin, CRC Press, Taylor and Francis Group, 2017, 6th Edition.
4. Transformations in Metals, Paul G. Shewmon, Indo American Books.

Online resources:

1. https://nptel.ac.in/courses/113/106/113106031/
2. en.wikipedia.org/wiki/Thermodynamics
3. web.mit.edu/16.unified/www/FALL/thermodynamics
4. materials.iisc.ernet.in/~abinand/courses/thermo

Course Code MM316	FUNCTIONAL MATERIALS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Classify functional materials
CO2	Discuss processing methods of functional materials
CO3	Describe structure-property correlations of functional materials
CO4	Select materials for advanced functional applications

Course Articulation Matrix:

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

Functional materials for electric vehicles, Li-ion and other battery materials, fuel cells, solar energy harvesting, Reflective and antireflective layers, Waste heat recovery materials,

Microstructure-property correlations, characteristic dimensions and spatial variations, volume fraction, rules of mixture and effective field parameters; characterization of properties of FMs, macrostructural thermomechanical properties, effective material properties for ceramic-metal FMs, basic mathematical modeling.

Applications: Case studies on use of functional materials for various applications

Text Books:

1. Deborah D.L. Chung, Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications, World Scientific, 2010.
2. William F. Smith, Javad Hashemi, Foundations of Materials Science and Engineering, Mc Graw Hill Education, 2009.
3. D.D.L. Chung: Composite Materials- Functional Materials for Modern Technologies, Springer, 2002.
4. Hui-Shen Shen: Functionally Graded Materials - Nonlinear Analysis of Plates and Shells, CRC Press, 2009.
5. Y. Miyamoto, W.A. Kaysser, B.H. Rabin, A. Kawasaki, R.G. Ford (Eds): Functionally Graded Materials- Design, Processing and Applications, Springer, 1999.

Online Resources:

1. https://www.researchgate.net/publication/227194436

Course Code: MM317	ENERGY MATERIALS	Credits 3-0-0: 3

Pre-Requisites:

Course Outcomes:

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

CO1	Identify the challenges in energy sector and describe the need of energy efficient materials technology.
CO2	Categorize materials and processes for energy production and conversion.
CO3	Describe materials selection and processes for energy storage.
CO4	Suggest suitable materials for specific energy applications.
CO5	Discuss materials development in the area of photovoltaic energy systems to date

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	1	-	-	1	1	-	-	-	1	-
CO2	3	-	-	-	-	1	1	-	-	1	-	1	2	2	2	1
CO3	3	-	-	-	-	1	1	-	-	1	-	1	2	2	2	1
CO4	3	-	-	-	-	1	1	-	-	1	-	1	-	2	2	1
CO5	3	-	-	-	-	1	1	-	-	2	1	1	1	1	2	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Energy production and environment, current energy landscape, gap between energy production and enery needs, conventional energy production via fossil fuel - scope and limitation, overview of energy sectors in India, Role of materials in energy production, alternative sources, Challenges associated with design and development of energy efficient materials technology.

Electrochemical Energy systems and Materials: Introduction to electrochemical route of energy generation, fuel cell technology and materials – molten carbonate fuel cell, solid oxide fuel cell, direct methanol fuel cell, Batteries – primary and secondary types, advances in lead-acid battery components, Lithium metal battery, Lithium ion battery, Nickel cadmium battery

Photovoltaics: Photovoltaic effect, photovoltaic systems and technologies – I, II & III generation technologies – single crystal Si, amorphous Si, thin film photovoltaics, organic photovoltaics, dye sensitised solar cell, perovskite solar cell.

Materials for energy storage: supercapacitors, hydrogen energy storage, phase change materials. Introduction to smart grid, light emitting diodes, thermocaloric, electrocaloric and magnetocaloric materials.

Text Books:

1. Introduction to materials for advanced energy systems, Colin, Tong, Springer, 2019
2. Arno Smelts, Solar Energy: The physics of engineering of photovoltaic conversion, technologies and systems, UIT Cambridge, 2016
3. D. M. Rowe, Materials, Preparation and Characterization in Thermoelectrics, Vols. 1& 2, CRC Press, 2012
4. C Julian and A Mauger, Lithium Batteries, Springer Nature, 2015

Reference Books:

1. Robert Huggins, Energy Storage, Springer Nature, 2015
2. T.C. McAuliffe, Hydrogen and Energy, Palgrave Macmillan, 1980

Online Resources:

https://nptel.ac.in/courses/115/107/115107116/

III – Year: II – Semester

Course Code MM351	CORROSION ENGINEERING	Credits 3-0-0: 3

Pre-requisites:

Course Outcomes:

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

CO1	Explain the principles of corrosion.
CO2	Evaluate corrosion mechanisms from thermodynamic principles.
CO3	Suggest suitable techniques for corrosion monitoring and its prevention.
CO4	Discuss the mechanism of high temperature oxidation.

Course Articulation Matrix:

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

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, Environmental effects- oxygen and oxidizers, velocity, temperature, corrosive concentration, galvanic coupling, Metallurgical aspects.

Forms of Corrosion: ASM Classification, Galvanic corrosion, Crevice corrosion, Pitting, Intergranular corrosion, Selective leaching, Erosion corrosion, Stress corrosion cracking, Hydrogen damage.

Modern Theory: Principles, Free energy, Applications of thermodynamics to corrosion, Pourbaix diagrams, Electrode kinetics, Exchange current density, Activation polarization, Concentration polarization, combined polarization, mixed electrode-potential Theory, Passivity.

Corrosion Prevention: Materials selection, Alteration of Environment, Design, Cathodic and anodic protection, Coatings.

Corrosion rate measurement: Tafel extrapolation, linear polarization, Introduction to vacuum devices, Rotary pump, Diffusion pump, turbo-molecular pump, Ion-pump, Basic vacuum system assembly and sequence of operation to create high vacuum.

High Temperature Corrosion: Mechanisms and kinetics- Pilling-Bed worth ratio, electrochemical and morphological aspects of oxidation, oxide defect structure, oxidation kinetics, effect of alloying, catastrophic oxidation, internal oxidation. High temperature materials- mechanical properties, oxidation resistance. Metal-Gas reactions-decarburization and hydrogen attack, corrosion of metals by sulphur components at high temperatures, hot corrosion of alloys.

Sea/Marine corrosion and Bacterial corrosion: Basic reactions and mechanisms involved.
Specific case studies of corrosion in advanced and critical materials.

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 Hand book, Vol 13A- Corrosion- Fundamentals, Testing & Protection, ASM, 2004.
2. Einar Bardal, Corrosion and Protection, Springer, 2004.

Online Resources:

1. https://nptel.ac.in/courses/113/104/113104082/ (Corrosion I, IIT Kanpur)

Course Code MM352	COMPUTATIONAL MATERIALS ENGINEERING	Credits 3-0-0: 3

Pre-requisites: Mathematics IV, Materials Thermodynamics and Kinetics, Transport Phenomena, Problem Solving and Computer Programming

Course Outcomes:

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

CO1	Discuss the importance of modelling and simulation in materials engineering
CO2	Solve one dimensional finite element problems
CO3	Explain the role of computational thermodynamics to predict phase diagrams
CO4	Discuss the requirements for molecular dynamics simulation
CO5	Apply data analytic techniques for materials engineering problems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO2	3	2	2	-	1	-	-	-	-	-	-	-	2	-	-	1
CO3	3	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-
CO4	3	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
CO5	3	2	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 engineering. Integrated computational materials engineering (ICME): introduction and recent trends.

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

Reference Books:

1. Ellad B. Tadmor, Ronald E. Miller, Modeling Materials (Continuum, Atomistic and Multiscale Techniques), Cambridge University Press, New York, 2011
2. Michael Heath, Scientific Computing: An introduction survey, McGraw Hill, 2002

Online Resources:

1. https://nptel.ac.in/courses/113/101/113101002/
2. https://nptel.ac.in/noc/courses/noc20/SEM1/noc20-me08/
3. https://ocw.mit.edu/courses/materials-science-and-engineering/3-320-atomistic-computer-modeling-of-materials-sma-5107-spring-2005/

Course Code MM353	MATERIALS CHARACTERIZATION	Credits 3-0-0: 3

Pre-requisites: PH183- Physics for Metallurgists, CY137- Chemistry for Metallurgists, and MM201- Physical Metallurgy

Course Outcomes:

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

CO1	Describe the principles of optical and electron microscopy.
CO2	Explain the principles of XRD for materials characterization.
CO3	Analyse thermal reactions using thermal analysis data.
CO4	Select a suitable characterization technique for microstructural and compositional analysis of materials.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Microscopy: Introduction to optical microscope~~, concepts of magnification, resolution, numerical aperture, depth of field, principles of image formation, DIC illumination, Hot stage microscopy, advantages and limitations~~. Electron microscopy, SEM and TEM, electron source, sample preparation, electron specimen interaction, lens arrangement, mode of imaging, bright field image, dark field image, image contrast, SAD. Comparison of OM, SEM and TEM. Advantages, limitations.

X-Ray diffraction: Properties of X-rays, X-Ray diffraction methods, Intensities of diffracted beam and structure factor, phase mixtures and phase diagram, determination of crystal structure, Phase identification.

Surface characterization techniques: EDS, WDX, XRF, XPS and AES, and EPMA.

Thermal analysis techniques: TGA, DSC, DTA and TMA

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.
5. ASM Handbook, Vol.10, Materials Characterization, ASM International, USA, 1998.

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 DC New 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)

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc21_mm07/preview

2. https://youtu.be/VR9d6RnmZww

Course Code: MM354	CERAMICS AND COMPOSITES TECHNOLOGY	Credits 3-0-0: 3

Course Outcomes:

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

CO1	State the properties and applications of metals, ceramics, polymers, composites.
CO2	Describe processing routes of ceramics and composites
CO3	Apply the rule of mixtures to estimate the properties of composites
CO4	Explain the strengthening mechanisms in composites
CO5	Select suitable ceramics and composite materials for a particular application

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-
CO3	3	-	-	2	-	-	-	-	-	-	-	-	-	-	-	3
CO4	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	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, non-oxide ceramics, production of ceramic powders through various techniques- sol gel, co-precipitation, solvent vaporization. Fabrication of ceramics, porous ceramics, glasses, glass ceramics, super plasticity in ceramics, bio ceramics, creep mechanism in ceramics, toughening mechanism in ceramics, applications of 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, various fibre materials-glass, carbon, boron etc, hybrid composites, Fabrication of composites- hand layout method, injection molding, compression molding, resin transfer, pultrution, etc., fracture behaviour of composites, Case studies.

Text Books:

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

Reference Books:

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

Online Resources:

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

Course Code MM355	COMPUTATIONAL MATERIALS ENGINEERING LABORATORY	Credits 0-1-2: 2

Pre-requisites: Problem Solving and Computer Programming Laboratory

Course Outcomes:

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

CO1	Calculate binary, pseudo-binary and ternary phase diagrams using ThermoCalc.
CO2	Solve one-dimensional heat transfer problems using Ansys.
CO3	Make use of LAMMPS to calculate lattice parameter/ melting point.
CO4	Apply explicit and implicit methods to solve diffusion problems.
CO5	Interpret materials experiments using data analytic techniques.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	1	-	-	3	-	-	-	1	2	-	1	2	3	-	-
CO2	3	1	2	-	3	-	-	-	1	2	-	1	2	-	-	2
CO3	3	1	-	-	3	-	-	-	1	2	-	1	2	2	-	-
CO4	3	1	-	-	3	-	-	-	1	2	-	1	2	-	-	-
CO5	3	1	2	-	3	-	-	-	1	2	-	1	2	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus: List of experiments (8-10 experiments will be performed from this list)

1) Plotting thermodynamic functions in unary, binary and ternary systems
2) Calculation of phase equilibria (unary system)
3) Calculation of Fe-C phase equilibria
4) Calculation of phase equilibria of non-ferrous alloy system
5) Calculation of isopleth in Fe-8Cr-C system
6) Finite element modelling of simple compression test/ 1D steady state heat transfer
7) Simulation of 1-D heat transfer
8) Using LAMMPS to measure the melting temperature of pure metals.
9) Solve transient diffusion equation using explicit finite difference method and Neumann boundary conditions. Compare the output with analytical solution.
10) Solve transient diffusion equation using explicit finite difference method and periodic boundary conditions. Compare the output with analytical solution.
11) Solve transient diffusion equation using implicit finite difference method and periodic boundary conditions. Compare the output with analytical solution.

Text Books:

1. Computational Materials Engineering Laboratory Manual

Reference Books:

1. Michael Heath, Scientific Computing: An introduction survey, McGraw Hill, 2002

Online Resources:

1. https://scilab.in/Completed_Books
2. http://www.opencalphad.com/
3. https://www.lammps.org/
4. https://nanohub.org/

Course Code MM356	MATERIALS CHARACTERIZATION LABORATORY	Credits 0-1-2: 2

Pre-Requisites: MM201-Physical Metallurgy

Course Outcomes:

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

CO1	Quantify microstructural features using image analysis tools.
CO2	Identify the modes of fracture
CO3	Analyse the chemical composition of materials through SEM-EDS.
CO4	Determine crystal structure of the material using XRD technique.
CO5	Determine the thermal properties of materials.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	3	-	-	-	1	2	-	-	-	1	-	3
CO2	3	-	-	-	3	-	-	-	1	2	-	-	-	1	-	3
CO3	3	3	-	-	3	-	-	-	1	2	-	-	-	1	-	3
CO4	3	-	3	-	3	-	-	-	1	2	-	-	-	1	-	3
CO5	3	-	3	-	3	-	-	-	1	2	-	-	-	1	-	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Image analysis of microstructures using OM.
2. Microstructural analysis using SEM.
3. Fractography analysis using SEM.
4. Chemical analysis of phases using SEM-EDS.
5. Determination of crystal structures, lattice parameter measurements, indexing and identification of phases using X-Ray Diffractometer
6. Determination of lattice strain and crystallite size using X-Ray Diffractometer
7. Oxidation kinetics using TGA / DTA.
8. Determination of thermal properties using DSC

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.
5. ASM Handbook, Vol.10, Materials Characterization, ASM International, USA, 1998.

Reference Books:

1. Materials Characterization Techniques Laboratory Manual

Online Resources:

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

8. https://www.youtube.com/watch?v=EItYvqOQe5w&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=1
9. https://www.youtube.com/watch?v=m8L-B4A75Ec&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=3
10. https://www.youtube.com/watch?v=qzSrPipUnRM&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=6
11. https://www.youtube.com/watch?v=GIqam7DEPY4&list=PLqj8pra18A5NUV8lYJKBfwMBGt5k9Fe5c&index=7
12. https://www.youtube.com/watch?v=Kilrxi2wIoA&t=7s
13. https://www.youtube.com/watch?v=9J83u8fxCRk
14. https://www.youtube.com/watch?v=QlD3H_s5sZ8

Course Code MM357	CORROSION ENGINEERING LABORATORY	Credits 0-1-2: 2

Pre-requisites:

Course Outcomes:

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

CO1	Determine the EMFs of common metals in standard electrolytes.
CO2	Recognize galvanic corrosion.
CO3	Evaluate corrosion rate from Tafel plots.
CO4	Evaluate oxidation rate of metals and alloys.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

List of Experiments:

1. Determination of EMFs of common metals.
2. Carryout Polarization Studies by using electrochemical workstation.
3. Evaluation of corrosion rate through Tafel plots.
4. Galvanic corrosion of copper-steel couple.
5. Stress-Corrosion Cracking of Steels.
6. Carry out Impedance studies by electrochemical workstation.
7. Determination of corrosion rate by weight loss measurements.
8. Find out rate of oxidation of alloys.

Reading:

Corrosion Laboratory manual

Course Code: ME361	FINITE ELEMENT METHOD	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Apply finite element method to solve problems in solid mechanics and heat transfer.
CO2	Solve problems in one dimensional structures including trusses, beams and frames.
CO3	Formulate FE characteristic equations for two dimensional elements and analyse plane stress, plane strain, and axi-symmetric and plate bending problems.
CO4	Solve the finite element formulations using MATLAB.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

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

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

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

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

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

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

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

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

Text Books:

1. Seshu P., Textbook of Finite Element Analysis, PHI, 2009.
2. Reddy, J.N., Finite Element Method in Engineering, Tata McGraw Hill, 2007.

Zeincowicz, The Finite Element Method for Solid and Structural Mechanics, 4th Edition, Elsevier 2007.

Course Code: MM362	CREEP, FATIGUE AND FRACTURE	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Classify deformation and fracture behaviour of materials at room and high temperature
CO2	Determine theoretical and experimental fracture strength of materials through EPFM, CTOD and J-integral
CO3	Predict the life of materials under fatigue loading
CO4	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
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3
CO2	3	-	-	1	-	-	-	-	-	-	-	-	-	2	-	3
CO3	3	-	-	2	-	-	-	-	-	-	-	-	-	2	-	3
CO4	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.

Text Books:

1. Deformation and Fracture Mechanics of Engineering Materials, R. W. Hertzberg, 4th Edition, John Wiley & Sons Inc., 2012.
2. Mechanical Behavior of Materials, M.A. Meyers 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.
5. Fundamentals of Creep in Metals and Alloys, Michael Kassner, 2nd Edition, Elsevier Science, 2009.

Course Code: MM363	FERROALLOY TECHNOLOGY	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Identify the use of ferroalloys in the production of steel
CO2	Discuss various reaction mechanisms during the production of ferroalloys
CO3	Discuss the technology of production of ferroalloys
CO4	Assess the environmental concern during production of ferroalloys

Course Articulation Matrix:

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

Theory of ferro alloys production: Concepts, thermodynamic and kinetic principles

Ferroalloy Processing: techniques, electrical and thermal processes, existing production process of important ferro alloys 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 ferro alloy technology

Energy and emission issues of the ferroalloys industry: Energy demand for ferroalloys making, CO_2 emission from ferroalloys production, recent developments in emission control.

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.
3. Production of Manganese ferroalloys, Sverre E. Olsen, Sverre Olsen, Merete Tangstad, Tor Lindstad, Tapir Akademisk Forlag, 2007, First edition.
4. The complete book on Ferroalloys, B.P. Bhardwaj, NIIR Project Consultancy Services, 2008, First edition.

Course Code: MM364	ATOM PROBE TOMOGRAPHY	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Describe the principles of mass spectroscopy and atom probe tomography
CO2	Explain the atom probe sample preparation methods
CO3	Correlate atomic scale structural information with the local chemical composition
CO4	Suggest the need for APT technique to characterize materials

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Atom Probe Tomography (APT) introduction, mass spectroscopy principles, ionization, field evaporation, mass-charge ratio, time-of-flight, description of field ion microscopy (FIM) and 3-dimensional atom probe tomography (APT) devices, Comparison of APT with transmission electron microscopy technique.

APT Sample Preparation: APT Sample preparation methods using mechanical polishing, electropolishing (micro-pulse polishing), and focussed ion beam techniques

Characterization of Materials: Case studies on multiphase materials, multilayer thinfilms and laminates, grain boundary compositional analyses, nanoprecipitates, phase evolutions such as GP zones formation in Al alloys during age hardening, applications of APT in nanomaterials, bulk metallic glasses, high entropy alloys and grain boundary engineered materials

Advances in APT technique: Scanning atom probe (SAP) and Laser assisted atom probe (LEAP), Challenges with high resistivity materials, semiconductors and organic materials, Recent improvements in detection efficiencies, Concluding remarks

Text Books:

4. M.K. Miller and R.G. Forbes, Atom Probe Tomography: Analysis at the Atomic Level. Springer Science & Business Media; 2012. (ISBN-13 : 978-0306464157)
5. M.K. Miller and R.G. Forbes, Atom-Probe Tomography: The Local Electrode Atom Probe, Springer Nature; 2014. (ISBN-13 : 978-1489974297)
6. T.F. Kelly, B.P. Geiser, R.M. Ulfig, T.J. Prosa, D.J. Larson, Local Electrode Atom Probe Tomography: A User's Guide. Springer; 2013. (ISBN-13 : 978-1461434351)

Reference Books:

3. M.K. Miller, A. Cerezo, M.G. Hetherington, and G.D.W. Smith, Atom probe field ion microscopy, 1996.

4. Lecture Notes

Online Resources:

1. T.F. Kelly, Atom Probe Tomography, Review of Scientific Instruments 78, 031101 (2007): https://aip.scitation.org/doi/full/10.1063/1.2709758

Course Code: MM365	NON-DESTRUCTIVE TESTING	Credits 3-0-0:3

Pre-Requisites: None

Course Outcomes:

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

CO1	Comprehend the basic principles of non-destructive testing (NDT) methods
CO2	Differentiate between NDT methods
CO3	Identify suitable surface NDE methods for defect detection
CO4	Discuss the necessary precautions against radiation hazards
CO5	Interpret the defects in engineering components using NDT methods

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
CO3	3	-	-	-	-	-	-	-	-	-	-	-	2	2	-	3
CO4	3	-	-	-	-	2	3	-	-	-	-	-	1	-	-	3
CO5	3	3	-	3	-	-	-	-	-	-	-	-	3	2	-	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

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

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

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

Ultrasonic Testing and Acoustic Emission Testing: Principles of ultrasonic testing, Ultrasonic propagation, Test techniques – normal and angle beam, Probes, Transducers, Applications, Advantages and limitations of ultrasonic testing.

Acoustic emission testing – principle, sources of acoustic emission, acoustic emission signal parameters, industrial applications

Text Books:

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

Reference Books:

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

Online Resources:

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

Course Code: MM366	MACHINE LEARNING FOR MATERIALS ENGINEERING	Credits 3-0-0: 3

Pre-Requisites: CS191 – Problem solving and computer programming

Course Outcomes:

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

CO1	Explain supervised and unsupervised machine learning algorithms
CO2	Analyse materials dataset with descriptive and predictive methods
CO3	Compare ML model performance for materials engineering problems
CO4	Propose new compositions using ML models

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Machine learning - Introduction to machine learning (ML), Supervised and unsupervised learning

Supervised learning – Regression, Linear and multi-variate regression cost functions, Logistic cost function, Regularization, Neural networks, Introduction and cost functions, SVM - Support Vector Machine – Intuition, Applying Machine learning, 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.

Anomaly detection - Gaussian distribution, Developing and evaluating an anomaly detection.

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

Textbooks:

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

Reference Books:

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

Online Resources:

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

IV – Year: I – Semester

Course Code: SM435	INDUSTRIAL MANAGEMENT AND METHODS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Explain the four evolutionary phases of the organizational theories, their circumstances and the consequences.
CO2	Examine organizational systems with time and motion study, inventory and quality for productivity improvements.
CO3	Explain the marketing management process in light of marketing mix and strategies
CO4	Calculate project schedule along with the interdependencies using PERT/CPM techniques.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction - Overview of organizational theory and theoretical perspectives

Rational and natural systems: The evolution of organizational theory - rational systems and Natural systems, Work study: Productivity and its role in the economy; Techniques for improving productivity; Method study; Principles of motion economy; Stop watch time study; Work sampling; Quality management: Dimensions of quality; Process control charts both attributes and variables. Sampling Plan - LTPD and AOQL concepts. Taguchi's Quality Philosophy; Quality function deployment; Introduction to TQM. QMS and EMS; Inventory Management: Purpose of inventories; Inventory costs; ABC classification; Economic Order Quantity (EOQ); P and Q systems of inventory control.

Organizational behaviour: The individual, The Group, Organization system (structure and culture).

Open systems and behavioral decision-making

Other management topics: Marketing management process; 4P's of marketing mix; Target marketing; Product life cycle and marketing strategies; Project Management: Project activities; Network diagrams; Critical path method (CPM); Programme Evaluation and Review Technique (PERT). Project crashing. Slack computations, Resource levelling.

Text Books:

1) Robbins, S. P., & Judge, T. A. Organizational behavior.2001.
2) Jones, G. R., & Jones, G. R. (2013). Organizational theory, design, and change. Upper Saddle River, NJ: Pearson
3) Taylor, F.W. 1916. Principles of Scientific Management, 30-144
4) Besterfield (2015). Total Quality Management. Pearson Education India; 4 editions

Reference Books:

1) Khanna, O. P. (1980). *Industrial engineering and management*. Dhanpat Rai.
2) Kottler, P., & Keller, K. L. (2011). Marketing Management 14e Global Edition.
3) Weber, M. Economy and Society 1978 pp.212-254, 956-975

Online Resources:

1. https://nptel.ac.in/courses/112/107/112107142/
2. https://nptel.ac.in/courses/112/107/112107292/

Course Code: MM401	METAL JOINING	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Differentiate welding processes
CO2	Describe the arc characteristics
CO3	Identify various welding defects and remedial measures
CO4	Discuss the principles of welding metallurgy
CO5	Explain the basic concepts and importance of additive manufacturing

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-
CO3	3	2	3	1	-	-	-	-	-	-	-	-	-	3	-	-
CO4	3	2	2	-	-	-	-	-	-	-	-	3	-	3	-	1
CO5	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

Welding metallurgy: heat flow in welding, solidification, weld microstructure, phase transformation, solidification cracking, post-weld heat treatment of weld joints, distortion and residual stresses in weldments, welding defects, inspection and remedies

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

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, Volume 6, USA, 1993.
6. Inspection and testing of weld joints Welding handbook, American Welding Society, 7th edition, USA, 1983.
7. Ian Gibson, David W Rosen, Brent Stucker: Additive Manufacturing Technologies- Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010

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.

Online Resources:

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

Course Code: MM402	METAL FORMING	Credits 3-0-0: 3

Pre-Requisites: Mechanical Behaviour of Materials

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

CO1	Summarise the stress-strain relationship.
CO2	Describe deformation behaviour, yield criteria and metal working.
CO3	Differentiate metal forming processes of forging, rolling, extrusion, and drawing.
CO4	Classify defects of forging, rolling, extrusion and drawing.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

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

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

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

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

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

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

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

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

Text Books:

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

Reference Books:

3. ASM Hand Book, Vol. 14: Forming and Forging, ASM International, 2012.

Online Recourses:

https://nptel.ac.in/courses/112/106/112106153/#
https://nptel.ac.in/courses/112/103/112103279/
https://nptel.ac.in/courses/112/107/112107250/

Course Code: MM403	NON-FERROUS EXTRACTIVE METALLURGY	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Identify techniques for extraction and refining of nonferrous metals.
CO2	Differentiate pyro-, and hydro-metallurgical techniques.
CO3	Design flow sheets for extraction and refining of metals.
CO4	Assess energy efficiency in extraction of Aluminum.

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Copper: Roasting, matte smelting, converting, fire-refining and electro-refining, New Processes- Flash Smelting, Continuous copper production, Hydrometallurgy of copper, recovery of copper from leach liquor.

Aluminium: Bayer process, its chemistry and practice. Hall-Heroult process: carbon anodes, theoretical principles, factors influencing the process, current and energy efficiencies.

Zinc: Pyrometallurgy, sinter-roasting and imperial smelting process. Hydrometallurgical extraction: roasting, leaching and electrowinning.

Lead: Blast furnace smelting, refining of lead bullion.

Titanium: Up-gradation of ilmenite and Kroll process.

Uranium: Acid and alkali processes for digestion of uranium ores. Production of reactor grade uranium and UO2.

Gold: Cyanidation process. Carbon-in pulp process.

Other important metals such as nickel and magnesium, major non-ferrous metal production in India.

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

Reference Books:

1. Fathi Habashi, Hand Book of Extractive Metallurgy, Vols I-IV, Wiley-VCH Breach, 1997.
2. W.G. Davenport, M. J. King, M. E. Schlesinger and A. K. Biswas, Extractive Metallurgy of Copper, Pergamon, 2002.

Online Resources:

https://nptel.ac.in/courses/113/105/113105021/ (IIT Kharagpur)

Course Code MM404	NON-DESTRUCTIVE TESTING LABORATORY	Credits 0-0-2: 1

Pre-Requisites: None

Course Outcomes:

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

CO1	Calibrate the non-destructive testing equipment
CO2	Operate non-destructive testing equipment
CO3	Evaluate defects in engineering components using NDT methods
CO4	Select NDT methods for engineering applications

Course Articulation Matrix:

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

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Perform visual inspection of weldments.
2. Detection of surface defects using fluorescent dye penetrant
3. Inspection on non-magnetic/magnetic materials and conductivity measurement by eddy current method
4. Inspection and evaluation of subsurface flaws using magnetic particle testing
5. Calibration of ultrasonic testing equipment using calibration (IIW type) block
6. Calibration of ultrasonic testing equipment using miniature angle beam block
7. Subsurface defect detection in welded plates using ultrasonic angle beam testing.
8. Industrial X-ray Radiographic film interpretation.

Text Books:

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

Reference Books:

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

Online Resources:

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

Course Code: MM405	METAL PROCESSING LABORATORY	Credits 0-0-2: 1

Pre-Requisites: None

Course Outcomes:

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

CO1	Perform arc welding process.
CO2	Evaluate microstructure and hardness profile of weldments.
CO3	Inspect metal defects using NDT techniques.
CO4	Demonstrate the effect of cold working and annealing on microstructure.
CO5	Practise rolling of copper, brass, plain carbon steel and stainless steel.

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	-	-	3	-	-	-
CO2	3	-	-	-	3	1	-	-	2	3	-	-	3	-	-	3
CO3	3	-	-	-	3	1	-	-	2	3	-	-	3	-	-	3
CO4	3	-	-	-	3	1	-	-	2	3	-	-	3	-	-	-
CO5	3	-	-	-	3	1`	-	-	2	3	-	-	3	-	-	-

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Demonstration of gas tungsten arc (GTA) welding of a given sample
2. Interpretation of the microstructure and hardness of the given weldment
3. Identification of metal defects using liquid penetrant and magnetic particle testing
4. Perform rolling of copper, brass, stainless steel and plain carbon steel using laboratory rolling mill
5. Study of mechanical properties and microstructural change of cold worked metals
6. Perform annealing of cold worked metal and observe microstructural changes
7. Determination of critical bend radii for crack formation
8. Effect of strain rate studies on mechanical properties

Text Books:

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

Reference Books:

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

Online Resources:

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

IV – Year: II – Semester

Course Code: MM498	SEMINAR	Credits 0-0-2: 1

Pre-Requisites: None

Course Outcomes:

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

CO1	Identify a topic in metallurgical and materials engineering research
CO2	Conduct thorough literature survey
CO3	Prepare a comprehensive report
CO4	Discuss the topic with peers using multimedia tools

Course Articulation Matrix:

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

1 - Slightly 2 - Moderately 3 – Substantially

Course Code: MM499	PROJECT WORK	Credits 0-0-8: 4

Pre-Requisites: None

Course Outcomes:

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

CO1	Identify the research problem based on literature survey
CO2	Propose the plan of research work
CO3	Conduct experimental/simulation work
CO4	Analyse the experimental/simulation data
CO5	Prepare a comprehensive report
CO6	Deliver an oral presentation using ICT tools

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	3		3					2		2	3	1	2	2	
CO2	3	3	3	3			2		2		2	3	1	2	2	
CO3	3		3	3	3	2			2		2		2	2	2	1
CO4	3	3	3	3	3				2		2	3	2	2	2	2
CO5								3	2	3	2					
CO6								3	2	3	2					

1 - Slightly 2 - Moderately 3 – Substantially

Course Code: MM461	ADVANCED ENGINEERING MATERIALS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Discuss the need and requirements for advanced materials development.
CO2	Explain the unique structures of advanced materials
CO3	Discuss principles and applications of bulk metallic glasses and meta materials
CO4	Differentiate high entropy alloys from conventional alloys
CO5	Suggest an advanced material for an industrial application

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	2	-	-	-	-	-	-	-	-	1	-	2	1	-
CO2	3	-	1	-	-	-	-	-	-	-	-	-	-	2	1	-
CO3	3	-	1	-	-	-	-	-	-	-	-	-	-	2	1	-
CO4	3	-	1	-	-	-	-	-	-	-	-	-	-	2	1	-
CO5	3	-	2	3	-	-	-	-	-	-	-	1	-	2	1	-

1 - Slightly 2 - Moderately 3 – Substantially

Syllabus:

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

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

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

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

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

Text Books:

1. Bulk Metallic glasses, C. Suryanarayana, A. Inoue, CRC Press, 2nd ed., 2017.
2. High-Entropy Alloys, B.S. Murty, J.W. Yeh, S. Ranganathan, Butterworth-Heinemann publications, 2014.
3. Metamaterials: Theory, Design, and Applications, Tie Jun Cui, David Smith, Ruopeng Liu, Springer US publications, 1st ed., 2010.
4. Quasicrystals: An Introduction to Structure, Physical Properties and Applications, J.B. Suck, M. Schreiber, P. **Häussler**, Springer-Verlag Berlin Heidelberg publications, 1st ed., 2002.
5. Fundamentals of Radiation Materials Science: Metals and Alloys, Gary S. Was, Springer International Publication, 2017.

References:

1. Bulk Metallic Glasses: An Overview, Michael K. Miller, Peter Liaw, Springer US publications, 1st ed., 2008.
2. High-Entropy Alloys Fundamentals and Applications, Michael C. Gao, Jien-Wei Yeh, Peter K. Liaw, Yong Zhang, Springer International Publishing Switzerland 2016.
3. Metamaterials: Physics and Engineering Explorations, Nader Engheta, Richard W Ziolkowski, Wiley-IEEE Press, 2006.

4. Quasicrystals, Volume 3, Takeo Fujiwara, Yasushi Ishii, Elsevier Science publications, 1st ed., 2007.
5. New Geometries for New Materials, Eric A. Lord, Alan L. Mackay, S. Ranganathan, Cambridge University Press, 2006.

Course Code: MM462	MATERIALS FOR EXTREME ENVIRONMENTS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Comprehend the principles of complex material-environment interactions
CO2	Apply the themodynamic and metallurgical principles to choose the right material for combined high temperature, high pressure environments
CO3	Discuss the novel processing routes for emerging materials for extreme environments
CO4	Predict the plausible material failure mechanism for materials specific to nuclear industry
CO5	Recommend the suitable composition and microstructure for space and aviation applications

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	2	-	-	-	-	1	-	-	1	-	-	2	3	2	-
CO2	3	2	1	-	-	-	-	-	-	1	-	-	3	3	2	-
CO3	3	-	1	-	-	-	1	-	-	1	-	-	3	-	3	-
CO4	3	1	2	1	-	-	-	-	-	1	-	2	3	2	-	3
CO5	3	2	2	1	-	-	-	-	-	1	-	2	3	-	3	-

1 - Slightly 2 - Moderately 3 – Substantially

Syllabus:

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

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

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

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

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

Text Books:

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

Reference Books:

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

Course Code: MM463	SURFACE ENGINEERING	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Explain surface engineering principles for metallic and non-metallic substrates
CO2	Compare surface modification processes
CO3	Assess the quality of surface coatings
CO4	Suggest suitable surface modification process to combat friction, wear, corrosion and oxidation

Course Articulation Matrix:

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

1 - Slightly 2 - Moderately 3 – Substantially

Syllabus:

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

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

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

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

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

Text Books:

1. J. R. Davis, Surface Engineering for corrosion and wear resistance, ASM International, 2001.
2. J. R. Davis, Surface hardening of steels-understanding the basics, ASM International, 2002.

Reference Books:

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

Course Code: MM464	NUCLEAR METALLURGY	Credits 3-0-0: 3

Pre-Requisites:

Course Outcomes:

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

CO1	Explain the concepts of nuclear reactor engineering
CO2	Classify reactor components and their materials
CO3	Identify techniques for disposal of radioactive wastes
CO4	Explain processing of nuclear grade materials

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	1	-	-	-	-	-	-	-	-	-	3	-	-	-
CO2	3	-	1	-	-	-	-	-	-	-	-	-	3	1	-	-
CO3	3	-	3	-	-	-	2	-	-	-	-	-	3	-	-	-
CO4	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, neutron cross sections, moderation of neutrons, multiplication factor. Fission reactions.

Nuclear Reactor Components: Reactors and Materials. Classification of nuclear reactors. Materials for nuclear reactors viz., fuels, moderators, control rods, coolants, reflectors and structural materials. Fabrication of fuel and cladding materials.

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.

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. H. S. Ray, R. Sridhar and K. P. Abraham, Extraction of Non-Ferrous Metals, Affiliated East-West Press, 1985.
5. Geoffrey F. Hewitt and John G. Collier, Introduction to Nuclear Power, Taylor and Francis, 1997.
6. K. Almenas and R .Lee, Nuclear Engineering: An Introduction, Springer Verlag, 1992.
7. TatjanaJevremovic, Nuclear Principles in Engineering, Springer, 2009.
8. Kenneth D. Kok, Nuclear Engineering Hand Book, CRC Press, 2009.

Course Code: MM465	REFRACTORY AND RARE METAL EXTRACTION	Credits: 3-0-0: 3

Course Outcomes:

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

CO1	Identify ore break down techniques.
CO2	Explain concentration techniques for leach solutions.
CO3	Design flow sheets for extraction rare and refractory metals.
CO4	Describe high temperature reduction techniques.

Course Articulation Matrix:

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

1 - Slightly 2 - Moderately 3 – Substantially

Syllabus:

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

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

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

Text Books:

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

Reference Books:

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

Course Code: MM466	POLLUTION AND ITS CONTROL IN METALLURGICAL INDUSTRIES	Credits 3-0-0: 3

Pre-requisites: None

Course Outcomes:

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

CO1	Identify the sources of pollution from metallurgical industries.
CO2	Quantify pollutants from process industries.
CO3	Propose methods for prevention of pollution.
CO4	Perform case studies on pollution control in metallurgical industries.

Course Articulation Matrix:

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

1- Slightly 2- Moderately 3- Substantially

Syllabus:

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

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

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

Text books:

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

Reference books:

1. Industrial Safety and pollution control handbook: National Safety Council and Associate publishers Pvt. Ltd, Hyderabad, 1993.
2. Kreith F. and Tchobanoglous G.: Handbook of Solid Waste Management, 2 Ed; Mc Graw Hill, 2002.
3. Pasquale Cavaliere, Ironmaking and Steelmaking processes - Greenhouse emissions, control and reduction, Springer, 2016.
4. G L Datta, K B De, A Nag, Foundry Moulding Materials and Pollution, New Age Publishers, 2005.
5. Bhaskar Nath, Georgi Stefanov Cholakov, Pollution Control Technologies, Vol III, EOLSS Publishers, 2009.

Online resources:

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

Course Code: MM467	METALLURGICAL WASTE RECYCLING	Credits 3-0-0: 3

Pre-requisites:

Course Outcomes:

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

CO1	Identify types and sources of metallurgical waste.
CO2	Discuss the impact of metallurgical waste on environment and economics
CO3	Suggest methods for conservation of energy in metallurgical processes.
CO4	Comprehend recycling of metallurgical waste.

Course Articulation Matrix:

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

1- Slightly 2- Moderately 3- Substantially

Syllabus:

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

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

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

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

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

Text books:

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

Reference books:

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

Online resources:

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

Course Code: MM468	MATERIALS SELECTION AND DESIGN	Credits 3-0-0: 3

Pre-requisites: MM302 Mechanical Behaviour of Materials, MM353 Materials Characterization

Course Outcomes:

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

CO1	Discuss materials selection criteria for engineering applications.
CO2	Describe the properties and applications of different classes of materials.
CO3	Suggest thermal treatment methods for modifying microstructure and mechanical properties.
CO4	Select materials for structural, functional and bio applications.

Course Articulation Matrix:

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

1 - Slightly 2 - Moderately 3 – Substantially

Syllabus:

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

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

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

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

Text Books:

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

Reference Books:

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

3. M. F. Ashby and K. Johnson, Materials and Design, Butterworth Publication, 2002

Online Resources:

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

Course Code: MM469	HIGH TEMPERATURE MATERIALS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

CO1	Explain the principles of oxidation of metals and alloys
CO2	Classify materials for high temperature applications
CO3	Explain mechanisms of creep, thermal fatigue, oxidation and hot corrosion
CO4	Select materials for high temperature applications

Course Articulation Matrix:

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

1 - Slightly 2 - Moderately 3 – Substantially

Syllabus:

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

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

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

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

Text Books:

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

Reference Books:

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

Course Code: MM470	ADVANCED MATERIALS CHARACTERIZATION TECHNIQUES	Credits 3-0-0: 3

Pre-Requisites: MM353-Materials Characterization

Course Outcomes:

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

CO1	Describe the advanced microscopic, spectroscopic, diffraction and surface characterization techniques.
CO2	Explain the working principles and specimen requirements of advanced characterization tools
CO3	Compare advanced characterization techniques in terms of their capabilities and application
CO4	Suggest suitable characterization techniques for a particular measurement/analysis

Course Articulation Matrix:

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

1 - Slightly 2 - Moderately 3 – Substantially

Syllabus:

Introduction: Relevance of advanced characterization to materials development, scientific understanding of phenomena in materials technology.

Advanced microscopic techniques: Electron-materials interactions; TEM: HRTEM, STEM, In-situ TEM; SEM-EBSD, in-situ SEM; AFM, STM.

Advanced spectroscopic techniques: UV-Visible spectroscopy, infra-red spectroscopy (FTIR), Raman.

Advanced diffraction techniques: Review of basic diffraction theory; Various SAXS techniques and its applications in characterizing material: SAXS, GISAXS. Syncroton: Principle,capability; Properties of neutron radiation; neutron sources; Small and High angle neutron scattering; Examples.

Advanced surface characterization techniques: XPS, AES, SIMS - Importance of surface characterization techniques; Physical principles of XPS, Photoelectric effects; Instrumentation, XPS patterns; Spin orbital Splitting; Quantitative analysis, Chemical effect, chemical shift, XPS imaging; Auger electron generation; Principle, Chemical effect, Quantitative analysis, Depth profiling, Applications; Static and Dynamic Secondary Ion Mass, Common modes of analysis, Depth Profiling, quantitative and Qualitative analysis; Comparison surface analysis techniques.

Atom probe tomograghy: Introduction, technique and capability

Text Books:

1. Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC press, 2008.
2. Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Wiley, 2009 (ebook)
3. D.B. Williams and C.B.Carter, Transmission Electron Microscopy, Plenum Press, 2009.
4. Terry L.Barr, Modern ESCAThe Principles and Practice of X-Ray Photoelectron Spectroscopy, CRC press, 1994
5. Willmott, Philip. An introduction to synchrotron radiation: techniques and applications. John Wiley & Sons, 2019.
6. Joseph Goldstein, Dale E. Newbury, David C. Joy, and Charles E. Scanning Electron Microscopy and X-ray Microanalysis, Springer Science, 2018, 4th Ed.
7. Lefebvre-Ulrikson, Williams, François Vurpillot, and Xavier Sauvage. Atom probe tomography. Academic Press, 2016.

Reference Books:

1. A. K. Tyagi, Mainak Roy, S. K. Kulshreshtha and S. Banerjee, Advanced Techniques for Materials Characterization, Materials Science Foundations (monograph series) Volumes 49– 51, 2009.

2. C.R. Brundle, C.A. Evens, Jr, S. Wilson (Editors), Encyclopedia of Materials Characterization, Butterworth-Heinmann, Boston, 1992.
3. Miller, Michael K. Atom probe tomography: analysis at the atomic level. Springer Science & Business Media, 2012.

Online Resources:

1. http://www.digimat.in/nptel/courses/video/113104004/L01.html
2. https://www.youtube.com/watch?v=FnYNjKabmxU
3. https://www.youtube.com/watch?v=eR2323Evz3U
4. https://www.youtube.com/watch?v=KngkLz1fg98

Course Code: MM471	METALLURGICAL FAILURE ANALYSIS	Credits 3-0-0: 3

Pre-Requisites: MM302 Mechanical Behaviour of Materials, MM353-Materials Characterization

Course Outcomes:

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

CO1	Explain reasons for failure of materials
CO2	Differentiate fracture modes and failure mechanisms
CO3	Determine fracture toughness of materials
CO4	Predict life of materials under mechanical loading
CO5	Examine failure analysis through case studies.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO2	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO3	3	1	-	2	-	-	-	-	-	-	-	-	-	2	-	2
CO4	3	2	2	2	-	-	-	-	-	-	-	-	-	2	-	2
CO5	3	2	-	2	-	-	-	-	-	-	-	-	-	2	-	2

1 - Slightly 2 - Moderately 3 – Substantially

Syllabus:

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

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

Tools and techniques in failure analysis.

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

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

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

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

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

Text Books:

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

Reference Book:

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

Course Code: MM472	INTRODUCTION TO NANO SCIENCE AND TECHNOLOGY	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

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

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:

Introduction: defining nanotechnology, nanoscale comparison, Challenges of this size scale. Nanoscience vs Nanotechnology.

Classification of Nanomaterials: Challenges of this Size Scale, Application area & opportunity, Classification According to their origin, dimensions & structural configuration; nanocomposite.

Size Effect: Structural differences on the nanoscale, Factors Influencing Properties of nanomaterials, Surface Area and Energy, effect of size on optical, electrical, physical & chemical properties.

Nanocarbon: Classifications of carbon-based nanomaterials; carbon black & its applications; Fullerene: Definition, discovery and structure; Properties- Solubility, Hydrated Fullerene, Superconductivity, Endohedral fullerenes, Existence in the nature, Synthesis (discover) of C60.

Carbon Nanotubes (CNT): Introduction and definition, discovery, Rolling-up a graphene sheet to form a tube, Chiral Vector; Types of CNTs, Properties of CNTs, Synthesis of CNTs- Laser Ablation method, Synthesis with CO2 laser, Electric-Arc Method, Solar energy reactor, Chemical vapor Deposition (CVD), Comparison of different synthesis methods.

Purification & Sorting of CNTs: The most common impurities, process of purification, Unbundling CNTs, Sorting of Carbon Nanotube, Purity Evaluation.

Growth Mechanism of CNT: Tip-growth model & Base-growth model, Grow-in-place Vs. grow-then-place approach; Defects in Carbon nanotubes- Types of defects, Stone-Wales Defects, Role of defects on different properties.

Graphene: Introduction, defining graphene, Graphene Superlatives, Discovery of Graphene, Salient features of the structure, Amazing Mechanical Properties, Electrical Properties, Thermal Conductivity, Optical properties, why graphene is different, Synthesis of Graphene- Top-down approach & Bottom up approach, Mechanical Exfoliation, Hummers Method, Epitaxial Growth, Chemical Vapour Deposition, Electrochemical Exfoliation, Laser Scribing, N-doped Graphene.

Applications: Early Applications, Applications in Electrical engineering, Electronics engineering, Mechanical engineering, Biodevices, Energy storage; New Applications-Glass-based electronics, Antibiotics, Ultrasonic Microphones, Lubricant, Mechanical Watch, Solar cells, Camera lenses, NFC Antenna, Super-Silk, Microbats, Water Purification, Sensors; Graphene's future, Challenges Surrounding Graphene.

Synthesis of nanomaterials:

Physical Methods: Mechanical Methods, Methods based on Evaporation, Sputter Deposition, Chemical Vapour Deposition, Electric Arc Deposition, Ion Beam Technique, Molecular Beam Epitaxy.

Chemical Methods: Synthesis of Metal nanoparticles by colloidal route, Sol-Gel Method, Hydrothermal synthesis, Sonochemical Synthesis, Microwave Synthesis.

Nanofluids: Introduction, Characteristic, Methods for Producing Nanoparticles/Nanofluids, Nanofluid Structure, Effect of nanoparticles in NF, Advantages and challenges, Applications.

Ferrofluid: Introduction, Synthesis of Magnetite Nanocrystals, Applications.
Natural Nanomaterials: Introduction, Biomimicry, lotous effect and its applications, Phenomenon of iridescence in butterflies and its applications, Gecko's Sticky Feet, Shark Skin, Toucan Beaks, Water Striders.

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

Service codes from MMED

Course Code: MM186	MATERIALS SCIENCE AND ENGINEERING	Credits 3-0-0: 3

*For Chemical Engg.

Pre-Requisites: General Physics and General Chemistry

Course Outcomes:

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

CO1	Classify the materials and discuss their applications.
CO2	Describe the crystal structure, constitution and microstructure of materials.
CO3	Suggest ferrous and non-ferrous alloys for different applications based on their properties.
CO4	Differentiate the properties and applications of ceramics, polymers and composites.
CO5	Select suitable advanced materials for electronic and thermochemical applications

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1		1		1		2						1				
CO2		1	3	3				2				1				
CO3		1	3	3		2						1				
CO4		1	3	3		2						1				
CO5		1	2	2		2						1				

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Historical materials, Introduction and classification of materials.

Crystal Geometry and Constitution of Alloys: Space lattices, Unit cells, Crystal structure, Crystal directions and planes, Crystal imperfections- Point defects, Line defects, Surface defects, Volume defects; Types of solid solutions- substitutional and interstitial; Hume-Rothery rules for solid solutions, Construction and interpretation of binary equilibrium diagrams-isomorphous, eutectic and peritectic-type diagrams, Intermediate phases and phase rule.

Plain Carbon Steels, Cast Irons and Alloy Steels: Iron-carbon phase diagram, Types of steels- low, medium and high carbon steels, Cast irons: white, grey, nodular, and malleable cast irons, Alloy steels: Stainless steels and their applications in chemical industries; Heat treatment-annealing, normalizing, hardening, tempering.

Non-ferrous Metals and Alloys: Properties and applications of - Cu and its alloys, Al and its alloys, Age hardening, Ti and its alloys, Ni-based alloys.

Ceramics, Polymers and Composites: Ceramics - Crystalline ceramics, Glasses, Properties and applications of ceramics; Polymers – Polymerization, Thermoplastics and thermosetting plastics, Properties and applications of polymers; Composites – Concept of composites, Matrix and reinforcement, Rule of mixtures, Classification of composites, Applications of composites.

Advanced Materials: Materials for electronics: Materials for solar cells, photovoltaics, fuel cells; Shape memory alloys, Phase change materials, High temperature materials for subcritical, super critical and ultra-super critical boilers, Hydrogen energy storage materials, nuclear materials.

Text Books:

1. W.D. Callister (Adapted by R. Balasubramaniam), Materials Science and Engineering, 2nd ed. (2014), Wiley India, New Delhi (ISBN: 978-8126541607)
2. V. Raghavan, Materials Science and Engineering: A First Course, 6thed. (2015), Prentice Hall ofIndia Learning Pvt. Ltd., Delhi (ISBN: 978-8120350922)
3. S. H. Avner, Introduction to Physical Metallurgy, 2nd ed. (1997), McGraw-HillEducation Publishers,New York, USA (ISBN: 978-0074630068)

Reference Books:

5. D.S. Clark and W. Varney, Physical Metallurgy for Engineers, 2nd ed. (2004) CBS Publishers and Distributors New Delhi (ISBN: 978-8123911786)
6. V. Raghavan, Physical Metallurgy: Principles and Practice, 2nd ed. (2012) Prentice Hall of IndiaLearning Pvt. Ltd., Delhi (ISBN: 978-8120330122)

Online Resources:

1. https://nptel.ac.in/courses/112/106/112106293/

Course Code: MM235	MATERIALS ENGINEERING	Credits 3-0-0: 3

*For MED

Pre-Requisites: Nil

Course Outcomes:

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

CO1	Describe the crystal structure and constitution of alloys.
CO2	Describe methods of determining mechanical properties and their suitability for applications.
CO3	Classify steels and cast irons, and discuss their applications.
CO4	Describe the properties and applications of non-ferrous metals and alloys.
CO5	Describe the forms of corrosion and suggest methods to prevent it.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CO1	2	3	2	1	2	-	1	-	-	-	-	1	2	1		
CO2	2	3	2	1	2	-	1	-	-	-	-	1	2	1		
CO3	2	3	1	1	1	-	3	-	-	-	-	1	2	1		
CO4	2	3	1	1	2	-	1	-	-	-	-	1	2	1		
CO5	2	3	2	1	2	-	3	-	-	-	-	1	2	1		

Syllabus:

Introduction to materials engineering, Classification of materials- Metals and alloys, Ceramics, Polymers and Composites

Crystal geometry and Constitution of alloys: Space lattices, Unit cells, Crystal structure, Crystal directions and planes, Crystal imperfections- Point defects, Line defects, Surface defects, Volume defects; Types of solid solutions- substitutional and interstitial; Hume-Rothery rules for solid solutions, Construction and interpretation of binary equilibrium diagrams- isomorphous, eutectic and peritectic-typediagrams, Intermediate phases and phase rule

Mechanical properties: Elasticity and plasticity in materials, Stress-strain curve, Resolved shearstress, Tensile properties, Hardness and hardness measurement, Impact properties, Fatigue, Creep.

Steels and Cast irons: Iron-carbon phase diagram, Types of steels- low, medium and high carbon steels, stainless steels, alloy steels and their applications; Heat treatment-annealing, normalizing, hardening, tempering, surface hardening; Cast irons, types- white, grey, malleable and nodular, Properties and applications of cast irons

Non-ferrous metals and alloys: Properties and applications of - Cu and its alloys, Al and its alloys,Age hardening, Ti and its alloys, Ni-based alloys.

Ceramics, Polymers and Composites: Introduction; properties and applications of ceramics, polymers, and composites

Corrosion and Corrosion protection: Corrosion- significance, EMF and galvanic corrosion, Major forms of corrosion - uniform, two-metal, crevice, pitting, erosion corrosion, environmentally induced cracking, Corrosion testing- gravimetric analysis and electrochemical methods, Influence of microstructure on corrosion resistance, and remedial passivation methods

Text Books:

1. W.D. Callister (Adapted by R. Balasubramaniam), Materials Science and Engineering, 2nd ed. (2014), Wiley India, New Delhi (ISBN: 978-8126541607)

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