

Revised Course / Curriculum / Syllabus in compliance of NEP-2020

B. Tech. in Metallurgical and Materials Engineering (MME) and Minor in MME

Program Learning Objectives:	Program Learning Outcomes:
Program Goal 1: The B.Tech program in Metallurgical and Materials Engineering aims to equip graduates with the necessary knowledge, skills, and values to succeed in professional careers related to metallurgical and materials engineering.	Program Learning Outcome 1a: Upon successful completion of the B.Tech program in Metallurgical and Materials Engineering, graduates will be able to identify, formulate, and analyse complex engineering problems related to metallurgical and materials engineering. Program Learning Outcome 1b: Students will be able to understand the science behind the functioning mechanism of metals, ceramics, polymers and glass
Program Goal 2: Apply fundamental principles of science and engineering to solve complex problems in metallurgical and materials engineering and cultivate critical thinking and problem-solving skills in students to address real-world challenges in the metallurgy and materials domain.	Program Learning Outcome 2: Student will be able to apply research-based knowledge and methodologies, including experimental design, data analysis, and interpretation, to investigate complex problems in metallurgical and material engineering. Graduates will be capable to carry out research work in their area of interest either in academic area or in industry.
Program Goal 3: Expose the students to the scientific and engineering concepts on metals, ceramics, polymer and composites and apply engineering principles to design, develop, and improve materials and processes for specific applications.	Program Learning Outcome 3a: Students will be well versed with the concepts of microscopic analysis, characterization techniques, metallurgical testing, polymer synthesis & analysis, nano & electro ceramics, plasma-coating and flash sintering, mineral beneficiation & process metallurgy. Program Learning Outcome 3b: Students will be able to design and develop new engineering materials with desired properties based on demands of various engineering sectors.
Program Goal 4: To impart hand-on exposure to modern laboratory equipment through structured laboratory experiments.	Program Learning Outcome 4a: Students will be able to correlate the theoretical concepts with the experiments and will be ready to apply the experimental knowledge in industries. Program Learning Outcome 4b: Students will be ready for quality control, higher studies and research work in the domain of metallurgical and materials engineering.
Program Goal 5: To inculcate research aptitude in the students and prepare the students to be industry-ready after the completion of their B. Tech. programme.	Program Learning Outcome 5: Students will be able to design solutions for complex engineering problems related to materials, considering public health, safety, cultural, societal, and environmental factors. In addition, apply ethical principles and

	commit to professional ethics and social responsibility as a metallurgical and materials engineer. Graduate will be able to launch start-ups as entrepreneur to create job opportunities in the country.
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Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	MA1101	Calculus and Linear Algebra	3	1	0	4.0
2.	CS1101	Foundations of Programming	3	0	3	4.5
3.	PH1101/ PH1201	Physics	3	1	3	5.5
4.	CE1101/ CE1201	Engineering Graphics	1	0	3	2.5
5.	EE1101/ EE1201	Electrical Sciences	3	0	3	4.5
6.	HS1101	English for Professionals	2	0	1	2.5
TOTAL			15	2	13	23.5

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	MA1201	Probability Theory and Ordinary Differential Equations	3	1	0	4
2.	CS1201	Data Structure	3	0	3	4.5
3.	CH1201/ CH1101	Chemistry	3	1	3	5.5
4.	ME1201/ ME1101	Mechanical Fabrication	0	0	3	1.5
5.	ME1202/ ME1102	Engineering Mechanics	3	1	0	4
6.	IK1201	Indian Knowledge System (IKS)	3	0	0	3
TOTAL			15	3	9	22.5

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	MM2101	Introduction to Metallurgical and Materials Engineering	3	0	0	3
2.	MM2102	Mineral Processing and Process Metallurgy	3	0	3	4.5
3.	MM2103	Thermodynamics and Phase Equilibria	3	0	3	4.5
4.	MM2104	Transport Phenomena	3	1	0	4
5.	MM2105	Fundamentals of Polymer Science and Technology	3	0	0	3
6.	HS21XX	HSS Elective - I	3	0	0	3
TOTAL			18	1	6	22

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	MM2201	Iron and Steel Making	3	1	0	4
2.	MM2202	Techniques of Materials Characterization - I	3	0	3	4.5
3.	MM2203	Phase Transformation and Diffusion	3	1	0	4
4.	MM2204	Mechanical Behaviour of Materials	3	0	3	4.5
5.	MM2205	Welding and Solidification	3	0	0	3
6.	XX22PQ	IDE-I	3	0	0	3
TOTAL			18	2	6	23

Sl. No.	Subject Code	SEMESTER V	L	T	P	C
1.	MM3101	Thermomechanical Processing of Metallic Materials	3	0	2	4
2.	MM3102	Computational Materials Science	2	1	0	3
3.	MM3103	Engineering Polymers	3	0	2	4
4.	MM3104	Ceramic Science and Technology	3	0	2	4
5.	MM3105	Metallography and Heat Treatment Laboratory	0	0	2	1
6.	XX31PQ	IDE-II	3	0	0	3
TOTAL			14	1	8	19

Sl. No.	Subject Code	SEMESTER VI	L	T	P	C
1.	MM3201	Techniques of Materials Characterization - II	3	0	3	4.5
2.	MM3202	Corrosion and Corrosion Prevention	3	0	2	4
3.	MM3203	Functional Materials	3	0	0	3
4.	MM3204	Non-ferrous Metals and Alloys	3	0	0	3
5.	MM3205	Capstone Laboratory	0	0	4	2
6.	MM3206	Metals Processing Laboratory	0	0	3	1.5
TOTAL			12	0	12	18

Sl. No.	Subject Code	SEMESTER VII	L	T	P	C
1.	MM41XX	Departmental Elective - I	3	0	0	3
2.	MM41XX	Departmental Elective - II	3	0	0	3
3.	HS41XX	HSS Elective - II	3	0	0	3
4.	XX41PQ	IDE-III	3	0	0	3
5.	MM4198	Summer Internship*	0	0	12	3
6.	MM4199	Project – I	0	0	12	6
TOTAL			12	0	24	21

Note :

*** For specific cases of internship after VIth Semester, the performance evaluation would be made on joining the VIIth Semester and graded accordingly in the VIIth Semester:**

Note :

a) (i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening vacation between Semester VI and VII that may be done in industry / R&D /

Academic Institutions including IIT Patna. The evaluation would comprise **combined grading based on host supervisor evaluation, project internship report after plagiarism check and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the three components stated herein.

a) (ii) Further, on return from internship, students will be evaluated for internship work through combined grading based on host supervisor evaluation, project internship report after plagiarism check, and presentation evaluation by the parent department with equal weightage of each component.

b) (i) In the VIIth semester, students can opt for a semester long internship on recommendation of the DAPC and approval of the Competent Authority.

b) (ii) On approval of semester long internship, at the maximum two courses (properly mapped/aligned syllabus) at par with institute electives may be opted from NPTEL and / or SWAYAM and the other two more should be done at the institute through course overloading in any other semester (either before or after the internship) and/or during following summer semester.

b) (iii) The candidates opting two courses from NPTEL and / or SWAYAM would be required to appear in the examination at the Institute as scheduled in the Academic Calendar.

Sl. No.	Subject Code	SEMESTER VIII	L	T	P	C
1.	MM42XX	Departmental Elective - III	3	0	0	3
2.	MM42XX	Departmental Elective - IV	3	0	0	3
3.	MM42XX	Departmental Elective - V	3	0	0	3
4.	MM4299	Project – II	0	0	16	8
TOTAL			9	0	16	17
GRAND TOTAL (Semester I to VIII)			166			

ELECTIVE GROUPS

Sl. No.	Subject Code	Departmental Elective - I	L	T	P	C
1.	MM4101	Environmental Sustainability and Industrial Safety	3	0	0	3
2.	MM4102	Glass Science and Technology	3	0	0	3
3.	MM4103	Semiconductor Materials and Devices	3	0	0	3

Sl. No.	Subject Code	Departmental Elective - II	L	T	P	C
1.	MM4104	Thin Films	3	0	0	3
2.	MM4105	Heat Treatment of Steel	3	0	0	3
3.	MM4106	Creep, Fatigue and Fracture	3	0	0	3

Sl. No.	Subject Code	Departmental Elective - III	L	T	P	C
1.	MM4201	Smart Polymers	3	0	0	3
2.	MM4202	Energy Materials	3	0	0	3

Sl. No.	Subject Code	Departmental Elective - IV	L	T	P	C
1.	MM4203	Electroceramics	3	0	0	3
2.	MM4204	Biomaterials	3	0	0	3

Sl. No.	Subject Code	Departmental Elective - V	L	T	P	C
1.	MM4205	Crystallographic Texture and Analysis	3	0	0	3
2.	MM4206	Furnace and Refractories	3	0	0	3
3.	MM4207	Composite Science and Technology	3	0	0	3

Interdisciplinary Elective (IDE) Courses for B. Tech. (Available to students other than Dept. of MME)

Sl. No.	Subject Code	Interdisciplinary Elective (IDE)	L	T	P	C
1.	MM2206	Structure and Properties of Materials	3	0	0	3
2.	MM3106	Microscopy and X-ray Diffraction	3	0	0	3
3.	MM4107	Nanomaterials	3	0	0	3

Minor in Material Science & Engineering:

Sl. No.	Subject Code	Subject Name	L	T	P	C
1.	MM2101	Introduction to Metallurgical and Materials Engineering	3	0	0	3
2.	MM2202	Techniques of Materials Characterization	3	0	3	4.5
3.	MM3103	Engineering Polymers	3	0	0	3
4.	MM3203	Functional Materials	3	0	0	3
5.	MM4103	Semiconductor Materials and Devices	3	0	0	3

Total Credits: 16.5

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	MA1101	Calculus and Linear Algebra	3	1	0	4.0
2.	CS1101	Foundations of Programming	3	0	3	4.5
3.	PH1101/PH1201	Physics	3	1	3	5.5
4.	CE1101/CE1201	Engineering Graphics	1	0	3	2.5
5.	EE1101/EE1201	Electrical Sciences	3	0	3	4.5
6.	HS1101	English for Professionals	2	0	1	2.5
TOTAL			15	2	13	23.5

Course Number	MA1101
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Calculus and Linear Algebra
Learning Mode	Lectures and Tutorials
Learning Objectives	To provide the essential knowledge of basic tools of Differential Calculus, Integral Calculus, Vector spaces and Matrix Algebra.
Course Description	This course provides a foundation for Calculus and Linear Algebra. Topics related to properties of single and two variable functions along with their applications will be discussed. In addition fundamentals of linear algebra and matrix theory with applications will also be discussed.
Course Content	Differential Calculus (12 Lectures): Limit and continuity of one variable function (including ε-δ definition). Limit, continuity and differentiability of functions of two variables, Tangent plane and normal, Change of variables, chain rule, Jacobians, Taylor's Theorem for two variables, Extrema of functions of two or more variables, Lagrange's method of undetermined multipliers. Integral Calculus (10 Lectures): Riemann integral for one variable functions, Double and Triple integrals, Change of order of integration. Change of variables, Applications of Multiple integrals such as surface area and volume. Vector Spaces (12 Lectures): Vector spaces (over the field of real numbers), subspaces, spanning set, linear independence, basis and dimension. Linear transformations, range and null space, rank-nullity theorem, matrix of a linear transformation. Matrix Algebra (8 Lectures): Elementary operations and their use in getting the rank, inverse of a matrix and solution of linear simultaneous equations, Orthogonal, symmetric, skew-symmetric, Hermitian, skew-Hermitian, normal and unitary matrices and their elementary properties, Eigenvalues and Eigenvectors of a matrix, Cayley-Hamilton theorem, Diagonalization of a matrix.
Learning Outcome	Students completing this course will be able to: 1. Understand various properties of functions such as limit, continuity and differentiability. 2. Learn about integrations in various dimension and their applications. 3. learn about the concept of basis and dimension of a vector space. 4. define Linear Transformations and compute the domain, range, kernel, rank, and nullity of a linear transformation. 5. compute the inverse of an invertible matrix. 6. solve the system of linear equations. 7. Apply linear algebra concepts to model, solve, and analyze real-world problems.
Assessment Method	Quiz /Assignment/ MSE / ESE

Textbooks:

1. Thomas, G. B., Hass, J., Heil, C. and Weir M. D., "Thomas' Calculus", 14th Ed., Pearson Education, 2018
2. Kreyszig, E., "Advanced Engineering Mathematics", 10th Ed., Wiley India Pvt. Ltd, 2015

Reference Books:

1. Jain, R. K. and Iyenger, S. R. K., "Advanced Engineering Mathematics", 5th Ed., Narosa Publishing House, 2017
2. Axler, S., "Linear Algebra Done Right", 3rd Ed., Springer Nature, 2015
3. Strang, G., "Linear Algebra and Its Applications" 4th Ed., Cengage India Private Limited, 2005

Course Number	CS1101
Course Credit	3-0-3-4.5
Course Title	Foundations of Programming
Learning Mode	Offline
Learning Objectives	- To understand the fundamental concepts of programming - To develop the basic problem-solving skills by designing algorithms and implementing them. - To learn about various data types, control statements, functions, arrays, pointers, and file handling. - To achieve proficiency in debugging and testing a C program
Course Description	This introductory course provides a solid foundation in programming principles and techniques. Designed for students with little to no prior programming experience, it covers fundamental concepts such as variables, data types, control structures, functions, and basic data structures. Students will learn to write, debug, and execute programs using a high-level programming language. Emphasis is placed on developing problem-solving skills, logical thinking, and the ability to write clear and efficient code. By the end of the course, students will be equipped with the essential skills needed to pursue more advanced studies in computer science and software development.
Course Outline	Introduction and Programming basics, Expressions Control and Iterative statements, Functions, Arrays, Recursion vs. Iteration Pointers, 2D-Array with pointers, Structures, String, Dynamic memory allocation, File handling, Contemporary programming languages, and applications Practical component: Lab to be conducted on a 3-hour slot weekly. It will be conducted with the theory course so the topics for problems given in the lab are already initiated in the theory class.
Learning Outcome	- Understanding of Basic Syntax and Structure in C language - Proficiency in Data Types, Operators, and Control Structures - Function Implementation and learn to use them appropriately - Efficient Use of Arrays and Strings - Pointer Utilization - Ability to perform dynamic memory allocation and deallocation using malloc (), calloc (), realloc (), and free () functions. - Structured data management with structures and unions - Exposure of file Handling - Learning debugging and error Handling
Assessment Method	Internal (Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading

- Knuth, Donald E. The art of computer programming, volume 4A: combinatorial algorithms, part 1. Pearson Education India, 2011.
- P.J. Deitel and H.M. Deitel, C How To Program, Pearson Education (7th Edition)
- Brian W. Kernighan and Dennis M. Ritchie, The C Programming Language, Prentice-Hall
- A. Kelley and I. Pohl, A Book on C, Pearson Education (4th Edition)
- K. N. King, C PROGRAMMING A Modern Approach, W. W. Norton & Company

Course Number	PH1101/PH1201
Course Credit	3-1-3-5.5

Course Title	Physics
Learning Mode	Lectures and Tutorials
Learning Objectives	Complies with Program Goals 1 and 2
Course Description	This course deals with fundamentals in Classical mechanics, Waves and Oscillations and Quantum Mechanics. As a prerequisite, the mathematical preliminaries such as coordinate systems, vector calculus etc will be discussed in the beginning.
Course Outline	Orthogonal coordinate systems (Plane polar, Spherical, Cylindrical), concept of generalised coordinates, generalised velocity and phase space for a mechanical system, Introduction to vector operators, Gradient, divergence, curl and Laplacian in different co-ordinate systems. Central force problem and its applications. Rigid body rotation, vector nature of angular velocity, Finding the principal axes, Euler's equations; Gyroscopic motion and its application; Accelerated frame of reference, Fictitious forces. Potential energy and concept of equilibrium, Lennard-Jones and double-well potentials, Small oscillations, Harmonic oscillator, damped and forced oscillations, resonance and its different examples, oscillator states in phase space, coupled oscillations, normal modes, longitudinal and transverse waves, wave equation, plane waves, examples two- and three-dimensional waves. Michelson-Morley experiment, Lorentz transformation, Postulates of special theory of relativity, Time dilation and length contraction, Applications of special theory of relativity.
Learning Outcome	Complies with PLO 1a, 2a, 3a
Assessment Method	Quiz, Assignments and Exams

Suggested Readings:

Textbooks:

1. Engineering Mechanics, M. K. Harbola, 2nd ed., Cengage, 2012
2. D. Kleppner and R. J. Kolenkow, An introduction to Mechanics, Tata McGraw-Hill, New Delhi, 2000.
3. I. G. Main, Oscillations and Waves
4. H. G. Pain, The Physics of Vibrations and Waves, 1968
5. Frank S. Crawford, Berkeley Physics Course Vol 3: Waves and Oscillations, McGraw Hill, 1966.

References:

1. R. P. Feynman, R. B. Leighton and M. Sands, The Feynman Lecture in Physics, Vol I, Narosa Publishing House, New Delhi, 2009.
2. David Morin, Introduction to Classical Mechanics, Cambridge University Press, NY, 2007.
3. P. C. Deshmukh, Foundations of Classical Mechanics, Cambridge University Press, 2019

Course code	CE1101/CE1201
Course Credit (L-T-P-C)	1-0-3-2.5
Course Title	Engineering Graphics
Learning Mode	Lectures and Practical
Learning Objectives	Complies with PLO-1a 1. The course on engineering drawing is designed to introduce the fundamentals of technical drawing as an important form of conveying information. 2. Apply principles of engineering visualization and projection theory to prepare engineering drawings, using conventional and modern drawing tools. 3. Practice drawing orthographic projections, isometric views, and sectional views, of simple and combined solids in different orientations.
Course Description	This course will introduce drawing as a tool to represent a complex three-dimensional object on two-dimensional paper through methods of projections. The course explains the use of different drafting tools and the importance of conventions for uniformity and standardization of the interpretation of the drawings.
Course Outline	Fundamental of engineering drawing, line types, dimensioning, and scales. Conic sections: ellipse, parabola, hyperbola; cycloidal curves. Principle of projection, method of projection, orthographic projection, plane of projection, first angle of projection, Projection of points, lines, planes and solids. Section of solids: Sectional views of simple solids- prism, pyramid, cylinder, cone, sphere; the true shape of the section. Methods of development, development of surfaces. Isometric projections: construction of isometric view of solids and combination of solids from orthographic projections. Introduction to AutoCad and solving isometric problems.
Learning Outcome	After attending this course, the following outcomes are expected: a) The student will understand the basic concepts of engineering drawing. b) The student will be able to use basic drafting tools, drawing instruments, and sheets. c) The student will be able to represent three-dimensional simple and combined solid objects on two-dimensional paper. d) The student will be able to visualize and interpret the orientation of simple and combine solid objects.
Assessment Method	Laboratory Assignments (30%), Mid-semester examination (25%) and End-semester examination (45%).

Suggested Readings:

Textbooks:

1. N.D. Bhatt, Engineering Drawing, Charotar Publishing House.
2. Agrawal & Agrawal, Engineering Drawing, McGraw Hill.
3. Jolhe, Engineering Drawing.

References:

1. Engineering Drawing and Design by David Madsen

Course Number	EE1101/EE1201
Course Credit	3-0-3-4.5
Course Title	Electrical Sciences
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of all B. Tech programmes. The course aims at giving an overview of the entire electrical engineering domain from the concepts of circuits, devices, digital systems and magnetic circuits.
Course Outline	Circuit Analysis Techniques, Circuit elements, Simple RL and RC Circuits, Kirchoff's law, Nodal Analysis, Mesh Analysis, Linearity and Superposition, Source Transformations, Thevenin's and Norton's Theorems, Time Domain Response of RC, RL and RLC circuits, Sinusoidal Forcing Function, Phasor Relationship for R, L and C, Impedance and Admittance, Instantaneous power, Real, reactive power and power factor. Semiconductor Diode, Zener Diode, Rectifier Circuits, Clipper, Clamper, UJT, Bipolar Junction Transistors, MOSFET, Transistor Biasing, Transistor Small Signal Analysis, Transistor Amplifier and their types, Operational Amplifiers, Op-amp Equivalent Circuit, Practical Op-amp Circuits, Power Opamp, DC Offset, Constant Gain Multiplier, Voltage Summing, Voltage Buffer, Controlled Sources, Instrumentation Amplifier, Active Filters and Oscillators. Number Systems, Logic Gates, Boolean Theorem, Algebraic Simplification, K-map, Combinatorial Circuits, Encoder, Decoder, Combinatorial Circuit Design, Introduction to Sequential Circuits. Magnetic Circuits, Mutually Coupled Circuits, Transformers, Equivalent Circuit and Performance, Analysis of Three-Phase Circuits, Power measurement in three phase system, Electromechanical Energy Conversion, Introduction to Rotating Machines (DC and AC Machines). <u>Laboratory:</u> Experiments to verify Circuit Theorems; Experiments using diodes and bipolar junction transistor (BJT): design and analysis of half -wave and full-wave rectifiers, clipping and clamping circuits and Zener diode characteristics and its regulators, BJT characteristics (CE, CB and CC) and BJT amplifiers; Experiment on MOSFET characteristics (CS, CG, and CD), parameter extraction and amplifier; Experiments using operational amplifiers (op-amps): summing amplifier, comparator, precision rectifier, Astable and Monostable Multivibrators and oscillators; Experiments using logic gates: combinational circuits such as staircase switch, majority detector, equality detector, multiplexer and demultiplexer; Experiments using flip-flops: sequential circuits such as non-overlapping pulse generator, ripple counter, synchronous counter, pulse counter and numerical display; Power Measurement by two Wattmeter method; Open and Short Circuit Tests of Transformer.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams

Texts/References

1. C. K. Alexander, M. N. O. Sadiku, Fundamentals of Electric Circuits, 3rd Edition, McGraw-Hill, 2008.
2. W. H. Hayt and J. E. Kemmerly, Engineering Circuit Analysis, McGraw-Hill, 1993.
3. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, 6th Edition, PHI, 2001.
4. M. M. Mano, M. D. Ciletti, Digital Design, 4th Edition, Pearson Education, 2008.
5. Floyd, Jain, Digital Fundamentals, 8th Edition, Pearson.
6. David V. Kerns, Jr. J. David Irwin, Essentials of Electrical and Computer Engineering, Pearson, 2004.

7. Donald A Neamen, Electronic Circuits; analysis and Design, 3rd Edition, Tata McGraw-Hill Publishing Company Limited.
8. Adel S. Sedra, Kenneth C. Smith, Microelectronic Circuits, 5th Edition, Oxford University Press, 2004.
9. A. E. Fitzgerald, C. Kingsley Jr., S. D. Umans, Electric Machinery, 6th Edition, Tata McGraw-Hill, 2003.
10. D. P. Kothari, I. J. Nagrath, Electric Machines, 3rd Edition, McGraw-Hill, 2004.
11. Del Toro, Vincent. "Principles of electrical engineering." (No Title) (1972).

Course Number	HS1101
Course Credit	L-T-P-W: 2-0-1-2.5
Course Title	English for Professionals
Learning Mode	Offline
Learning Objectives	This course aims to help the students (a) attain proficiency in written English through the construction of grammatically correct sentences, utilization of subject-verb agreement principles, mastery of various tenses, and effective deployment of active and passive voice to ensure coherent and impactful written expression; (b) enhance oral communication skills by honing public speaking abilities, acquiring strategies to deliver persuasive presentations, and cultivating a polished telephone etiquette, enabling confident and articulate verbal communication; (c) foster active listening capabilities by recognizing different types of listening, and applying proven methods and strategies to improve active listening skills; (d) strengthen reading skills, including comprehension, interpretation, and critical analysis, to grasp diverse written materials and derive meaning from various types of texts encountered in academic and professional contexts; (e) develop adeptness in written communication for business purposes, encompassing the understanding of essential writing elements, mastery of appropriate writing styles thereby enhancing prospects for successful job interviews and subsequent professional endeavors.
Course Description	This academic course on communication skills aims to equip students with fluency in spoken and written English for effective expression in both academic and professional settings. By focusing on essential communication principles and providing practical experiences, students develop clarity, precision, and confidence in their communication. Through interactive discussions and exercises, students enhance critical thinking and adaptability in diverse contexts. Upon completion, students will excel in formal presentations, group discussions, and persuasive writing, enhancing their overall communication proficiency.
Course Outline	Unit I: Introduction to professional communication – LSRW - Phonetics and phonology Sounds in English Language – production and articulation – rhythm and intonation – connected speech - Basic Grammar and Advanced Vocabulary Sounds in English Language – production and articulation – rhythm and intonation – connected speech – persuading and negotiating – brevity and clarity in language. Unit II: Characteristics of Technical Communication: Types of communication and forms of communication - Formal and informal communication Verbal and non-Verbal Communication – Communication barriers and remedies Intercultural communication – neutral language Unit III: Comprehension and Composition – summarization, precis writing Business Letter Writing CV/ Resume – E-Communication Unit IV: Statement of Purpose, Writing Project Reports, Writing research proposal, writing abstracts, developing presentations, interviews – combating nervousness Tutorial: Listening Exercises, Speaking Practice (GDs, and Presentations), and Writing Practice Learning Outcome • Attain proficiency in written English, enabling the construction of grammatically correct sentences and coherent written expression through the use of appropriate grammar, tenses, and voice. • Enhance oral communication skills, including public speaking, persuasive presentation, and polished telephone etiquette, fostering confident and articulate verbal expression. • Cultivate active listening abilities, recognizing different listening types, overcoming obstacles, and employing strategies for attentive and effective communication. • Develop proficient written communication skills for business purposes, demonstrating understanding of essential writing elements, appropriate styles, and the creation of reports, notices, agendas, and minutes that effectively convey information.
Assessment Method	Class test + Quiz = 20%; Mid-semester = 25%; Assignment = 15%; End semester = 40%

Suggested Reading

1. Balzotti, Jon. Technical Communication: A Design-Centric Approach. Routledge, 2022.
2. Kaul, Asha, Business Communication. PHI Learning Pvt. Ltd. 2009
3. Laplante, Phillip A. Technical Writing: A Practical Guide for Engineers, Scientists, and Nontechnical Professionals. CRC Press, 2018.
4. Lawson, Celeste, et al. Communication Skills for Business Professionals, Second Edition. CUP, 2019.
5. Sharon Gerson and Steven Gerson. Technical Writing: Process and Product (8th Edition), London: Longman, 2013
6. Rentz, Kathryn, Marie E. Flatley & Paula Lentz. Lesikar's Business Communication Connecting in a Digital world, McGraw-Hill, Irwin.2012
7. Allan & Barbara Pease. The Definitive Book of Body Language, New York, Bantam,2004
8. Jones, Daniel. The Pronunciation of English, New Delhi, Universal Book Stall.2010
9. Savage, Alice. Effective Academic Writing. OUP. 2014
10. Swan and Alter. Oxford English grammar course. OUP. 201

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	MA1201	Probability Theory and Ordinary Differential Equations	3	1	0	4
2.	CS1201	Data Structure	3	0	3	4.5
3.	CH1201/CH1101	Chemistry	3	1	3	5.5
4.	ME1201/ME1101	Mechanical Fabrication	0	0	3	1.5
5.	ME1202/ME1102	Engineering Mechanics	3	1	0	4
6.	IK1201	Indian Knowledge System (IKS)	3	0	0	3
TOTAL			15	3	9	22.5

Course Number	MA1201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Probability Theory and Ordinary Differential Equations
Learning Mode	Lectures and Tutorials
Learning Objectives	To introduce the basic concepts of probability, statistics, and Differential equations.
Course Description	This course aims to cover basic concepts of probability, statistics and ordinary differential equations. In particular, popular distributions, random sampling, various estimators and hypothesis testing will be discussed. Students will also get exposure to the linear ordinary differential equations and their solution techniques.
Course Content	Probability (12 Lectures): Random variables and their probability distributions, Cumulative distribution functions, Expectation and Variance, probability inequalities, Binomial, Poisson, Geometric, negative binomial distributions, Uniform, Exponential, beta, Gamma, Normal and lognormal distributions. Statistics (10 Lectures): Random sampling, sampling distributions, Parameter estimation, Point estimation, unbiased estimators, maximum likelihood estimation, Confidence intervals for normal mean, Simple and composite hypothesis, Type I and Type II errors, Hypothesis testing for normal mean. Ordinary Differential Equations (20 Lectures): First order ordinary differential equations, exactness and integrating factors, Picard's iteration, Ordinary linear differential equations of n-th order, solutions of homogeneous and non-homogeneous equations (Method of variation of parameters). Systems of ordinary differential equations, Power series methods for solutions of ordinary differential equations. Legendre equation and Legendre polynomials, Bessel equation and Bessel functions.
Learning Outcome	Students will get exposure and understanding of: 1. Random variables and their probability distributions 2. Understand popular distributions and their properties 3. Sampling, estimation and hypothesis testing 4. Solution of ordinary differential equations 5. Solution of system of ordinary differential equations 6. Special functions arising as power series solutions of ordinary differential equations
Assessment Method	Quiz /Assignment/ MSE / ESE

Text Books:

1. Hogg, R. V., McKeane, J. and Craig, A. T., "Introduction to Mathematical Statistics", 8th Ed., Pearson Education India, 2021
2. S.M. Ross "An introduction to Probability Models, Academic Press INC, 11th edition.
3. Miller, I. and Miller, M., "John E. Freund's Mathematical Statistics with Applications", 8th Ed., Pearson Education India, 2013
4. S. L. Ross, Differential equations, 3rd Edition, Wiley, 1984
5. W. E. Boyce and R. C. Di Prima, Elementary Differential equations and Boundary Value Problems, 7th Edition, Wiley, 2001.

Course Number	CS1201
Course Credit	3-0-3-4.5
Course Title	Data Structure
Learning Mode	Offline
Learning Objectives	• Understand the principles and concepts of data structures and their importance in computer science. • Learn to implement various data structures and understand how different algorithms works. • Develop problem-solving skills by applying appropriate data structures to different computational problems. • Achieving proficiency in designing efficient algorithms.
Course Description	This course provides a comprehensive study of data structures and their applications in computer science. It focuses on the implementation, analysis, and use of various data structures such as arrays, linked lists, stacks, queues, trees, and graphs. Through theoretical concepts and practical programming exercises, this course aims to develop problem-solving and algorithmic thinking skills essential for advanced topics in computer science and software development.
Course Outline	• Introduction to Data Structure, • Time and space requirements, Asymptotic notations • Abstraction and Abstract data types • Linear Data Structure: stack, queue, list, and linked structure • Unfolding the recursion • Tree, Binary Tree, traversal • Search and Sorting, • Graph, traversal, MST, Shortest distance • Balanced Tree Practical component: Lab to be conducted on a 3-hour slot weekly. It will be conducted with the theory course so the topics for problems given in the lab are already initiated in the theory class.
Learning Outcome	• Understand Data Structure Fundamentals • Implement Basic Data Structures using a programming language • Analyse and Apply Algorithms • Design and Analyse Tree Structures • Understand the usage of graph and its related algorithms • Design and Implement Sorting and Searching Algorithms • Debug and Optimize Code
Assessment Method	Internal (Quiz/Assignment/Project), Mid-Term, End-Term

Suggested Reading

- Alfred V. Aho, John E. Hopcroft, Jeffrey D. Ullman, Data Structures and Algorithms, Published by Addison-Wesley
- Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest and Clifford Stein., Introduction to Algorithms,
- Mark Allen Weiss, Data Structures and Algorithm Analysis in Java
- Robert Sedgewick and Kevin Wayne, Algorithms
- Narasimha Karumanchi, Data Structures and Algorithms Made Easy

Course Number	CH1201/CH1101
Course Credit	3-1-3-5.5
Course Title	Chemistry
Learning Mode	Offline
Learning Objectives	The course aims to lay a foundation for all three branches of chemistry, viz. Organic, Inorganic, and Physical Chemistry. The course aims to nurture knowledge to appreciate the interface of chemistry with other science and Engineering branches by combining theoretical concepts and experimental studies.
Course Description	This course introduces basic organic chemistry, inorganic chemistry and Physical chemistry to understand fundamental laws that governs various reactions, reaction rates, equilibrium, and their applications in daily life through relevant experimentation.
Course Outline	Module 1: Thermodynamics: The fundamental definition and concept, the zeroth and first law. Work, heat, energy and enthalpies. Second law: entropy, free energy and chemical potential. Change of Phase. Third law. Chemical equilibrium. Conductance of solutions, Kohlrausch's law-ionic mobilities, Basic Electrochemistry. Module 2: Coordination chemistry: Crystal field theory and consequences color, magnetism, J.T distortion. Bioinorganic chemistry: Trace elements in biology, heme and non-heme oxygen carriers, haemoglobin and myoglobin; Organometallic chemistry. Module 3: Stereo and regio-chemistry of organic compounds, conformational analysis and conformers, Molecules devoid of point chirality (allenes and biphenyls); Significance of chirality in living systems, organic photochemistry, Modern techniques in structural elucidation of compounds (UV-Vis, IR, NMR). Module 4 (Lab Component): Experiments based on redox and complexometric titrations; synthesis and characterization of inorganic complexes and nanomaterials; synthesis and characterization of organic compounds; experiments based on chromatography; experiments based on pH and conductivity measurement; experiment related to chemical kinetics and spectroscopy.
Learning Outcome	Students will be able to 1. identify organic and inorganic molecules and relate them to daily life applications through experiments. 2. understand important hypothesis, laws and their derivations to intercept physical phenomenon of chemical reactions and apply them in hands-on experiments. 3. understand the importance of organic and inorganic molecules in our body and environment. 4. know important analytical techniques to intercept chemical entity. 5. approach organic and inorganic synthesis as a skillset for drug manufacturing, calculate limiting reagents and yields, use various analytical tools to characterize organic compounds, interpret and ascertain data related to Physical chemistry aspects and know laboratory safety measures, risk factors and scientific report writing skills.
Assessment Method	Theory: 20% Quiz and assignment, 30% Mid sem and 50% End semester exams for theory part (4 credits). Lab: 60% lab report, lab performance and assignment, 20% End semester exam for practical part, 20% viva/quiz (1.5 credits). Overall Weightage: Theory (70%), Lab (30%).

Suggested Reading:

Text books:

1. Vogel's Qualitative Inorganic Analysis, G. Svehla, 7th Edition, Revised, Prentice Hall, 1996.
2. A. J. Elias, S. S. Manoharan and H. Raj, "Experiments in General Chemistry", Universities

- Press (India) Pvt. Ltd., 1997.
3. A. J. Elias, A Collection of Interesting General Chemistry Experiments, revised edition, Universities Press (India) Pvt. Ltd., 2007.
 4. F. Albert Cotton, G. Wilkinson, C. A. Murillo, M. Bochmann, Advanced Inorganic Chemistry - 6th Edition New Delhi: Wiley India, 2008.
 5. K. Mukkanti, Practical Engineering Chemistry, B.S. Publications, Hyderabad, 2009.
 6. Shriver and Atkins inorganic chemistry / Peter Atkins, Tina Overton, Jonathan Rourke, Mark Weller, Fraser Armstrong-5th Edition – Oxford: UOP. 2012.
 7. Atkins' Physical Chemistry, Peter Atkins, Julio de Paula, James Keeler, Oxford University Press, 11th Edition 2017.
 8. K. L. Kapoor, A Textbook of Physical Chemistry, Vol: 1, 2 (6th Edition, 2019), Vol: 3 (5th Edition, 2020) MaGraw Hill.
 9. G. R. Chatwal, S. K. Anand, Instrumental Methods of Chemical Analysis, 5th Edition, Himalaya Publications, 2023.

	PLO-1	PLO-2	PLO-3	PLO-4	PLO-5	PLO-6	PLO-7	PLO-8
CLO-1	X	X	X	X	X	X	X	X
CLO-2	X	X		X	X			
CLO-3	X	X	X	X		X	X	
CLO-4	X	X		X	X	X	X	X
CLO-5			X	X	X			X

Course Number	ME1201/ME1101
Course Credit	0-0-3-1.5
Course Title	Mechanical Fabrication
Learning Mode	Fabrication work – hands on fabrication work in Workshop
Learning Objectives	Complies with PLOs 3-4. • This course aims to develop the concepts and skills of various mechanical fabrication methods. • Fabrication of metallic and non-metallic components, fabrication using bulk and sheet metals, subtractive and additive manufacturing methods, and assemble the parts
Course Description	This course is designed to fulfil the need of hand on experience about various approaches (conventional and CNC, subtractive and additive) of mechanical fabrication approaches. Prerequisite: NIL
Course Outline	The jobs for various shops should be planned such that they are the parts of an assembled item. The student groups will fabricate different parts in various shops which will involve some amount of their creativeness/input particularly in design and/or planning. Various components as required for the assembled part can be made using the following shops: Sheet Metal Working: Development, sheet cutting and fabrication of designated job using sheet metal (ferrous/nonferrous); Joining of required portions by soldering, in case part is desired to be made leak proof. Pattern Making and Foundry: Making of suitable pattern (wood); making of sand mould, melting of non-ferrous metal/alloy (Al or Al alloys), pouring, solidification. Observation/identification of various defects appeared on the component. Joining: Butt/lap/corner joint job fabrication as required of low carbon steel plates; weld quality inspection by dye-penetration test (non-destructive testing approach) of the component made. Demonstration of semi-automatic Gas Metal Arc welding (GMAW). Conventional machining: Operations on lathe and vertical milling to fabricate the required component. The fabrication of the component should cover various lathe operations like straight turning, facing, thread cutting, parting off etc., and operations using indexing mechanism on vertical milling. CNC centre: Fundamentals of CNC programming using G and M code; setting and operations of job using CNC lathe or milling, tool reference, work reference, tool offset, tool radius compensation to fabricate the component with a designed profile on Al/Al-alloy plate. 3D printing (Fused Filament Fabrication): (2 weeks) Create the model, select appropriate slicing and path for fabrication of a 3D job by layer deposition (additive manufacturing approach) using polymeric material. Demonstration on pattern fabrication using 3D printing.
Learning Outcome	• This course would enable the students to develop the concept of design, fabrication (subtractive and additive) for various engineering applications. Fabrication of components and assemble them. • The practical skill and hands on experience for various fabrication methods from bulk, sheet metal using conventional as well as CNC machines.
Assessment Method	Fabrication of components in each of the shops required for assembly of the given part; submission of reports for each shop, and quiz assessment.

Text and Reference books:

1. Hajra Choudhury, HazraChoudhary and Nirjhar Roy, 2007, Elements of Workshop Technology, vol. I, Mediapromoters and Publishers Pvt. Ltd.
2. W A J Chapman, Workshop Technology, 1998, Part -1, 1st South Asian Edition, Viva Book Pvt Ltd.
3. P.N. Rao, 2009, Manufacturing Technology, Vol.1, 3rd Ed., Tata McGraw Hill Publishing Company.
4. M.Adithan, B.S. Pabla, 2012, CNC machines, New Age International Publishers

Course Number	ME1202/ ME1102
Course Number	Engineering Mechanics
L-T-P-C	3-1-0-4
Pre-requisites	Nil
Semester	Spring
Learning Mode	Lectures
Learning Objectives	Complies with PLOs 1, 4 The objective of this first course in mechanics is to enable engineering students to analyze basic mechanics problems and apply vector-based approach to solve them.
Course Outline	Rigid body statics: Equivalent force system. Equations of equilibrium, Free body diagram, Reaction, Static indeterminacy. Structures: 2D truss, Method of joints, Method of section. Beam, Frame, types of loading and supports, axial force, Bending moment, Shear force and Torque Diagrams for a member. Friction: Dry friction (static and kinetic), wedge friction, disk friction (thrust bearing), belt friction, square threaded screw, journal bearings, Wheel friction, Rolling resistance. Centroid and Moment of Inertia Introduction to stress and strain: Definition of Stress, Normal and shear Stress. Relation between stress and strain, Cauchy formula. Stress in an axially loaded member and stress due to torsion in axisymmetric section
Learning Outcomes:	Following learning outcomes are expected after going through this course. - Learn and apply general mathematical and computer skills to solve basic mechanics problems. - Apply the vector-based approach to solve mechanics problems.
Assessment Method	Mid semester examination, End semester examination, Class test/Quiz, Tutorials

Reference Books

- H. Shames, Engineering Mechanics: Statics and dynamics, 4th Ed, PHI, 2002.
 - F. P. Beer and E. R. Johnston, Vector Mechanics for Engineers, Vol I - Statics, 3rd Ed, Tata McGraw Hill, 2000.
 - J. L. Meriam and L. G. Kraige, Engineering Mechanics, Vol I - Statics, 5th Ed, John Wiley, 2002.
 - E.P. Popov, Engineering Mechanics of Solids, 2nd Ed, PHI, 1998.
- F. P. Beer and E. R. Johnston, J.T. Dewolf, and D.F. Mazurek, Mechanics of Materials, 6th Ed, McGraw Hill Education (India) Pvt. Ltd., 2012.

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	MM2101	Introduction to Metallurgical and Materials Engineering	3	0	0	3
2.	MM2102	Mineral Processing and Process Metallurgy	3	0	3	4.5
3.	MM2103	Thermodynamics and Phase Equilibria	3	0	3	4.5
4.	MM2104	Transport Phenomena	3	1	0	4
5.	MM2105	Fundamentals of Polymer Science and Technology	3	0	0	3
6.	HS21XX	HSS Elective - I	3	0	0	3
TOTAL			18	1	6	22

Course Number	MM2101
Course Credit (L-T-P-C)	3-0-0 (3 AIU Credits)
Course Title	Introduction to Metallurgical and Materials Engineering
Learning Mode	Lectures
Prerequisite	None
Learning Objectives	To understand the theoretical description of crystal and bonding in solids and the atomic arrangement and defects in crystalline materials. To understand the structure-property correlation in materials.
Course Description	A foundational course delving into the interrelationship between microstructure, properties, and processing, providing understanding of the behaviour of various materials and their applications.
Course Content	Bonding in solids: Concept of energy versus interatomic separation for atoms, bonding in solids, primary interatomic bonding, secondary bonding. Properties of differently bonded solids. Property of materials in relation to crystal symmetry. Tensors. Structure of crystalline solids: Basic idea of lattice, crystalline and non-crystalline materials, unit cell, crystal systems, indexing planes and directions, Miller indices, coordination number, packing of atoms, voids, elements of symmetry. Defects in solids: Point, linear, planar and volume defects, equilibrium concentration of vacancies, Types of dislocations, Burgers vectors, slip systems, grain boundaries, twin and stacking faults. Mechanical properties of materials: Concept of stress and strain, Hooks law, elastic and plastic deformation, tensile properties, hardness. Structure-property correlation: Introduction to ceramic, polymer and composite – processing, structure, properties and applications.
Learning Outcome	Upon completion of this course the student will be able to: Identify the properties of material with respect to their crystal structure and bonding Correlate the influence of defects on material properties. Correlate the structure of crystalline materials with their properties.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Materials Science and Engineering, an Introduction: William D. Callister, 7th Ed., John Wiley and Sons, 2007.
2. Materials Science and Engineering: V. Raghavan, 6th Ed., Prentice Hall India, 2015.

Reference Books:

1. Physical Foundation of Materials Science: Günter Gottstein, Springer, 2004.
2. An Introduction to Metallurgy: Sir Alan Cottrell, 2nd Ed., Universities Press, 2000.

	CLO1	CLO2
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PLO1	X	
PLO2		X
PLO3	X	
PLO4		
PLO5		

Course Number	MM2102
Course Credit (L-T-P-C)	3-0-3 (4.5 AIU Credits)
Course Title	Mineral Processing and Process Metallurgy
Learning Mode	Lectures and Practical
Prerequisite	None
Learning Objectives	To understand various mineral processing techniques for metal extraction. To understand process technology for mineral beneficiation, extraction and refining of metals, especially non-ferrous metals.
Course Description	This course covers mineral beneficiation, separation techniques, and key metallurgical principles, focusing on thermodynamics, kinetics, and metallurgical processes.
Course Content	Mineral Engineering: Minerals of economic importance, laws of comminution, Principles of separation technologies (Gravity Separation, Froth Floatation, magnetic separation & Electrostatic separation) Beneficiation efficiency ratios and two product mass balance equation. Principles of Process Metallurgy: Thermodynamics (Free energy, Ellingham diagram, Predominance area Diagram), Kinetics (Rate laws, Order of reactions, solubility of gases in metal, Arrhenius Equation). Pyrometallurgy: Principles of drying, calcination, roasting, smelting (including flash smelting); Extraction of Fe, Cu, Pb, Ni, Mg, Zn, Ti. Hydrometallurgy: Theory of leaching, leaching techniques (bacterial leaching, Pressure leaching), leaching solvents, solvent extraction, Ion exchange, Cementation process, Examples (Bayer's process for Alumina and Sherritt-Gorden process for Cu, Ni, Co), rare metals. Electrometallurgy: Principles of electrolysis, Faraday's law of Electrolysis, Electro winning & electrorefining, Electrolysis of Fused salt (extraction of aluminium through Hall-Heroult process), Electrolysis of aqueous salt (extraction magnesium from sea-water through Dow's process). Refining of metals: Principles & Techniques of refining: Selective dissolution, Liquation, zone refining, chemical and electrochemical method.
Learning Outcome	Upon completion of this course the student will be able to: Apply appropriate knowledge for: Mineral Beneficiation (comminution and separation; extraction and refining of metals). Appreciate the importance of scientific concepts for mineral beneficiation, extraction of non-ferrous metals from ores including their refinement.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Mineral Processing Technology: B.A. Wills, 8th Ed., Butterworth Heinemann, Elsevier, 2015
2. Extraction of Nonferrous metals: H.S. Ray, R. Sridhar & K.P. Abraham, Affiliated East-West Press, 2018

3. Principles of extractive metallurgy: H.S. Ray & A. Ghosh, New Age International Publishers, 3rd Edition, 2019

Reference Books:

1. Chemical Metallurgy: J.J. Moore, 2nd Edition, Elsevier, 1990

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3		X
PLO4	X	
PLO5		

Course Number	MM2103
Course Credit (L-T-P-C)	3-0-3 (4.5 AIU Credits)
Course Title	Thermodynamics and Phase Equilibria
Learning Mode	Lectures and Practical
Prerequisite	None
Learning Objectives	To understand how thermodynamics is fundamental to the study of materials engineering and apply the thermodynamics for engineering problem solving. To understand the stability criteria of various systems (vapour-solid, solid liquid, liquid-vapour) under consideration.
Course Description	The course provides basic understanding of different laws of thermodynamics, enthalpy, entropy, Gibbs free energy, solution (Ideal and Regular) etc. The course will help to plot and understand phase diagram, which are essential for developing new materials.
Course Content	Introduction to Thermodynamics: Concept of state, reversible and irreversible processes, path and state functions, extensive and intensive properties, kinetic theory of gases. First Law of Thermodynamics: Internal energy, enthalpy, constant volume and pressure process, isothermal and adiabatic process and heat capacity. Second Law of Thermodynamics: Equilibrium, entropy, most probable microstate, statistical concepts of entropy, Thermodynamical functions, Maxwell's relations, Gibbs-Helmholtz stability. Third Law of Thermodynamics: Gibbs free energy vs temperature and Gibbs free energy vs. pressure, Clausius-Clapeyron equation, P-T diagram. Thermodynamic stability of materials. Ellingham diagram and its importance, application of electrochemical series. The behaviour of solutions, Phase equilibria, and phase diagram: Ideal solution, Gibb's-Duhem equation, Raoult's, and Henry's law, the activity of a component, concept of chemical potential, regular solutions, free energy-composition diagrams for ideal and regular solutions and its relation to phase diagram, Gibbs phase rule, eutectic and eutectoid, peritectic and peritectoid diagrams. Ternary phase diagrams. Binodal and spinodal decomposition in metals, ceramics and polymers.
Learning Outcome	Upon completion of this course, the student will be able to: Understand the practical implication of laws of thermodynamics. Apply the laws of thermodynamics to solve common industrial important reactions. Appreciate the implications of various systems in metallurgical/allied industry.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Introduction to Metallurgical Thermodynamics: David R. Gaskell, McGraw Hill, 4th Ed., 2009.
2. The laws of thermodynamics, P. Atkins, Oxford University Press. 2010
3. Phase Transformation: Porter and Easterling.

Reference Books:

1. Physical Chemistry of Metals: L. Darken and R.W. Gurry, McGraw-Hill, 1953.
2. Thermodynamics of Solids: Richard A. Swalin, 2nd Ed., Wiley, 1972.

	CLO1	CLO2
PLO1	X	
PLO2		
PLO3		X
PLO4	X	
PLO5		

Course Number	MM2103
Course Credit (L-T-P-C)	0-0-3 (1.5 AIU Credits)
Course Title	Thermodynamics and Phase Equilibria Laboratory
Learning Mode	Practical
Prerequisite	None
Learning Objectives	To understand how thermodynamics is fundamental to the study of materials engineering and apply the thermodynamics for engineering problem solving. To understand the stability criteria of various systems (vapour-solid, solid liquid, liquid-vapour) under consideration.
Course Description	The course provides basic understanding of different laws of thermodynamics, enthalpy, entropy, gibbs free energy, solution (Ideal and Regular) etc. The subject will help to plot and understand various types of phase diagram, which are essential for developing new materials.
Course Content	Introduction to programming using MATLAB/Python: Basics, loops, IF-Else conditioning, functions, solving equations Calculations of enthalpy, entropy, and free energy variation with temperature using MATLAB/Python for metals using sp. heat data from the database Calculation of driving force of phase transformation, concept of undercooling and supercooling using MATLAB Constructions of free energy vs composition diagram using ideal and regular solution models at different temperatures using MATLAB/Python and the concept of the isomorphous, eutectic phase diagram and miscibility Introduction to Thermo-Calc software, concept of CALPHAD, phase equilibria, property diagrams, and phase diagrams of multicomponent alloys using the Thermo-Calc software
Learning Outcome	Upon completion of this course, the student will be able to: Understand the practical implication of laws of thermodynamics. Apply the laws of thermodynamics to solve common industrial important reactions. Appreciate the implications of various systems in metallurgical/allied industry.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Introduction to Metallurgical Thermodynamics: David R. Gaskell, McGraw Hill, 4th Ed., 2009.
2. Atkins' Physical Chemistry: Twelfth Edition, Peter Atkins, Julio de Paula, and James Keeler, 2022, ISBN: 9780198847816
3. Phase Transformation: Porter and Easterling.
4. Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers, 7e: Rudra Pratap, Oxford University Press, 2017, ISBN: 978-0-19-060206-2
5. An Introduction to Python Programming for Scientists and Engineers: Johnny Wei-Bing Lin, Hannah Aizenman, Erin Manette Cartas Espinel, Kim Gunnerson, Joanne Liu, Cambridge University Press, 2022, ISBN 1108753485, 9781108753487

Reference Books:

1. Physical Chemistry of Metals: L. Darken and R.W. Gurry, McGraw-Hill, 1953.
2. Thermodynamics of Solids: Richard A. Swalin, 2nd Ed., Wiley, 1972

	CLO1	CLO2
PLO1	X	
PLO2	X	
PLO3		
PLO4	X	
PLO5		

Course Number	MM2104
Course Credit (L-T-P-C)	3-1-0 (4 AIU Credits)
Course Title	Transport Phenomena
Learning Mode	Lecture and Tutorial
Prerequisite	None
Learning Objectives	To develop fundamental concepts governing the transport of momentum, energy and mass. To demonstrate the common mathematical formulation of transport problems to the students.
Course Description	This course introduces dimensional analysis, fluid mechanics, heat and mass transfer, and reaction kinetics, emphasizing transport phenomena and practical engineering applications.
Course Content	Dimensional Analysis: Introduction; Dimensions and Units; Buckingham's π theorem. Momentum Transfer: Fluid Properties and fluid as a Continuum; Viscosity; Dimensional Formula and Units of Viscosity; Effect of Temperature and Pressure on Viscosity; Laminar flow and Turbulent flow; Flow: Rate and continuity equation; Losses in Pipes; Head loss due to friction; Flow measurement; Flow past immersed objects, packed & fluidized beds. Heat Transfer: Modes of Heat Transfer: Introduction to conduction, convection, and radiation; Conduction: Heat transfer through a wall, Composite walls with materials in series, Composite walls with materials in parallel, Multidimensional heat transfer problems; Convection: Types of Convection, Film heat transfer coefficients, Newton's Law of Cooling; Radiation: Black body radiation; Law: Stefan-Boltzmann, Kirchhoff's Law; Radiation Properties: Emissivity, Receiving Properties; Radiation heat transfer; Factors affecting; Thermal conductivity of gases, liquids, solid metals and alloys; Heat transfer with change of phases: solidification, melting problems. Mass transfer: Diffusion; Laws of diffusion; Fick's first law of diffusion; Fick's second law of diffusion; Factors affecting Mass transfer coefficient k, Parameters affecting convective mass transfer; Application of dimensionless analysis; Homogenization of alloys; Formation of surface layers. Introduction to kinetics: Basic kinetic laws, order of reactions, rate constant, elementary and complex reactions, rate limiting steps and Arrhenius equations, theories of reaction rates - simple collision theory, activated complex theory.
Learning Outcome	Upon completion of the course, students will be able to: Estimate transport properties such as viscosity, conductivity and diffusivity. Develop the conservative equations of laws of momentum, energy and mass
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Fundamentals of Heat and Mass Transfer; 5th Edition; F.P. Incropera and D.P. DeWitt, 2006; Wiley India.
2. Transport Phenomena; 2nd Edition; R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot; 2021; John Wiley & Sons, Inc.
3. Fundamentals of Momentum, Heat, and Mass Transfer; 4th Edition; Welty, James, Charles E. Wicks, R. E. Wilson, and Gregory L. Rorrer; 2000; New York: John Wiley and Sons Inc.,
4. Kinetics of Materials: R.W. Balluffi, S.M. Allen, and W.C. Carter, Wiley, 2005.

Reference Books:

1. Fundamental of Transport Phenomena and Metallurgical Process Modeling; Sujay Kumar Dutta; 2022; Springer
2. Transport Processes and Separation Process Principles; 4th Edition; C. J. Geankoplis; PHI Learning Private Limited., New Delhi.
3. Transport Phenomena in Materials Processing; D. R. Poirier, G. H. Geiger; 2016; Springer International Publishing.

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3		X
PLO4		
PLO5		

Course Number	MM2105
Course Credit (L-T-P-C)	3-0-0 (3 credits AIU Credits)
Course Title	Fundamentals of Polymer Science and Technology
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the structure-property correlation in polymers and develop knowledge of the mechanics underlying various polymerization techniques and polymer reactions. To understand the variables controlling the physical characteristics of polymers.
Course Description	This course will educate the students on the subject of polymers that constitute one of the most important materials used presently. The course will include fundamentals of synthesis, characterization, properties and also include discussion on the applications of polymers.
Course Content	Basic concepts: Molecular forces, chemical bonding, Configuration, Conformation, tacticity, molecular weight studies, molecular weight distribution, transitions in polymers, viscoelasticity, types of macromolecules, classification of polymers. Structure and property relationships: Amorphous and crystalline nature of polymers, factors affecting crystallization and melting, glassy state and glass transition temperature and factors influencing the glass transition temperature. Polymerization techniques: General features of chain growth polymerization - initiators, generation of initiators, free radical, anionic and cationic polymerization, ring opening polymerization, general features of step growth polymerization - mechanism of step growth polymerization, coordination polymerization, kinetics of addition, condensation and coordination polymerization, copolymerization mechanism and kinetics, homogeneous polymerization techniques- bulk, solution, heterogeneous polymerization techniques- emulsion, suspension, solid phase polymerization. Polymer solutions: Thermodynamics of polymer solutions, solution properties of polymers, solubility parameter, polymer chains' conformation in polymer solutions: Flory-Krigbaum and Flory-Huggins theories, solution viscosity, osmotic pressure, molecular size and molecular weight. Testing and characterization: End group analysis, colligative property measurement, light scattering, ultra-centrifugation, viscosity methods, gel permeation chromatography, IR, NMR, XRD, microscopy, thermal characterization, rheology/viscoelasticity, Mechanical properties testing - tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact and toughness. Advanced polymerization techniques: ATRP, RAFT.
Learning Outcome	Upon completion of this course the student will be able to: Recognize how polymers' structures and properties relate to one another. Choose appropriate polymerization techniques for polymer synthesis Select suitable characterization methods to characterize the polymers

Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.
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Text Books:

1. F.W. Billmeyer, Textbook of polymer science, 3rd ed., John Wiley & Sons, Asia, New Delhi, 1994.
2. R.J. Young and P. A. Lovell, Introduction to Polymers, 2nd ed., CRC Press (Taylor and Francis Group) 2004.

Reference Books:

1. Fundamental of Transport Phenomena and Metallurgical Process Modeling; Sujay Kumar Dutta; 2022; Springer
2. Transport Processes and Separation Process Principles; 4th Edition; C. J. Geankoplis; PHI Learning Private Limited., New Delhi.
3. Transport Phenomena in Materials Processing; D. R. Poirier, G. H. Geiger; 2016; Springer International Publishing.
4. V.R. Gowariker, N.V. Viswanathan, J. Sreedhar, Polymer Science, New Age International, 2010.

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3		X

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	MM2201	Iron and Steel Making	3	1	0	4
2.	MM2202	Techniques of Materials Characterization - I	3	0	3	4.5
3.	MM2203	Phase Transformation and Diffusion	3	1	0	4
4.	MM2204	Mechanical Behaviour of Materials	3	0	3	4.5
5.	MM2205	Welding and Solidification	3	0	0	3
6.	XX22PQ	IDE-I	3	0	0	3
TOTAL			18	2	6	23

Course Number	MM2201
Course Credit (L-T-P-C)	3-1-0 (4 credits AIU Credits)
Course Title	Iron and Steel Making
Learning Mode	Lecture and tutorial
Prerequisite	None
Learning Objectives	To understand the scientific principles for the production of iron and steel and process technology of ironmaking, steelmaking and continuous casting To introduce the emerging trends in iron and steelmaking technologies
Course Description	The course aims to instill in the students a scientific understanding of the iron and steel manufacturing process, from ore extraction to the final product, including its historical milestones.
Course Content	Ironmaking: Routes of modern steel making (BF-BOF, DRI-EAF), Thermodynamics of Ironmaking, Burden preparation (sintering, pelletization, coke making), Blast furnace Ironmaking (Design, operation, reactions and zones, direct & indirect reduction, burden distribution, Auxiliary fuel injection, RAFT calculations, RIST Diagram, Aerodynamics, development trends). Alternate routes of ironmaking: Sponge ironmaking, Smelting Reduction. Steelmaking Principles of Steelmaking: Basic thermodynamics & Kinetics of steelmaking. Primary Steelmaking: LD steelmaking converter, design, reactions, operations, refractories, development trends like Post combustion & slag splashing; EAF steelmaking. Secondary steelmaking: Ladle metallurgy, vacuum degassing, Inclusion refining. Casting of steel: Ingot Vs Continuous Casting, Continuous casting (Tundish Metallurgy, defects in CC products), neat net shape casting etc. Future trends: Clean steel & Hydrogen-assisted steelmaking.
Learning Outcome	Upon completion of this course the student will be able to: Appreciate the complexities in the production of iron and steel Apply the acquired knowledge to various processes like BF ironmaking, BOF steelmaking, Casting, EAF steelmaking etc Appreciate the latest green iron and steelmaking techniques
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. F.W. Billmeyer, Textbook of polymer science, 3rd ed., John Wiley & Sons, Asia, New Delhi, 1994.
4. R.J. Young and P. A. Lovell, Introduction to Polymers, 2nd ed., CRC Press (Taylor and Francis Group) 2004.

Reference Books:

1. Fundamental of Transport Phenomena and Metallurgical Process Modeling; Sujay Kumar Dutta; 2022; Springer

2. Transport Processes and Separation Process Principles; 4th Edition; C. J. Geankoplis; PHI Learning Private Limited., New Delhi.
3. Transport Phenomena in Materials Processing; D. R. Poirier, G. H. Geiger; 2016; Springer International Publishing.
4. V.R. Gowariker, N.V. Viswanathan, J. Sreedhar, Polymer Science, New Age International, 2010.

	CLO1	CLO2
PLO1	X	
PLO2	X	
PLO3		X

Course Number	MM2202
Course Credit (L-T-P-C)	3-0-3 (4.5 AIU Credits)
Course Title	Techniques of Materials Characterization - I
Learning Mode	Lecture and Practical
Prerequisite	None
Learning Objectives	To understand how material characterization is of paramount importance to the study of materials science. To understand the strength and weaknesses of different characterization techniques and gain hands-on training on different characterization techniques.
Course Description	The course involves i) the study of the crystal structure of solids. ii) the structural analysis of material at different length scales, such as micro, nano and angstrom levels, using different characterization techniques.
Course Content	Introduction: Importance and the need for materials characterization, crystal system, miller indices, Bravais lattice. Diffraction: Basics of diffraction and interference of light, Young's double slit experiment, interpretation of diffraction from the single slit and multiple slits. X-ray Diffraction: Generation of X-Rays, X-Ray Diffraction (XRD), Bragg's Law, Atomic scattering factor, structure factor, indexing of diffraction patterns, selection rules, estimation of peak intensity, phase identification and analysis by XRD, determination of structure and lattice parameters, strain and crystallite size measurements through XRD, effect of temperature on XRD. Reciprocal lattice and Ewald's sphere. Optical Microscopy: Principles of optical microscopy, magnification, Rayleigh criterion, resolution limitation, Airy disk, depth of focus and field. Electron diffraction: Wave properties of the electron, electron-matter interactions, ring patterns, spot patterns, and Laue zones. Scanning Electron Microscopy: Principle, construction, and operation of Scanning Electron Microscope, SE and BSE imaging modes, Elemental analysis using Energy dispersive analysis of X-rays, sample preparation of different materials for SEM. Transmission electron microscope: Principle, construction, and working of Transmission Electron Microscope (TEM), the origin of contrast: mass-thickness contrast, electron diffraction pattern, Bright field and dark field images, sample preparation.
Learning Outcome	Upon completion of this course, the student will be able to: Understand the working principle and applications of various characterization techniques Choose an appropriate technique to characterize various microstructural aspects Characterize the microstructure of various materials by themselves
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Elements of X-Ray Diffraction: B.D. Cullity and S.R. Stock, 3rd Ed., Pearson, 2001.
2. Scanning Electron Microscopy and X-Ray Microanalysis: Joseph Goldstein, Eric Lifshin, Charles E. Lyman, David C. Joy and Patrick Echlin, 3rd Ed., Springer, 2003.

Reference Books:

1. Transmission Electron Microscopy: A Textbook for Materials Science: David B. Williams and C. Barry Carter, Springer, 2009.
2. Structure of Materials: An Introduction to Crystallography, Diffraction and Symmetry, Marc De Graef, Michael E. McHenry; 2nd Ed., Cambridge University Press, 2012.

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3	X	
PLO4		X

Course Number	MM2202
Course Credit (L-T-P-C)	0-0-3 (1.5 AIU Credits)
Course Title	Techniques of Materials Characterization – I Laboratory
Learning Mode	Practical
Prerequisite	
Learning Objectives	To understand how material characterization is of paramount importance to the study of materials science. To understand the strength and weaknesses of different characterization techniques and gain hands-on training on different characterization techniques.
Course Description	The course involves i) the study of the crystal structure of solids. ii) the structural analysis of material at different length scales, such as micro, nano and angstrom levels, using different characterization techniques.
Course Content	Sample preparation: Cutting, grinding, and polishing of metal samples. Powder sample preparation. Practical aspects of X-ray diffraction analysis will be emphasized; hands-on experience in qualitative and quantitative analysis techniques, use of electronic databases, and phase analysis using XRD data. Stereographic projections. Practical aspects of SEM: Hands-on training in microstructural analysis through SEM, Learning SE, BSE mode, and EDS Practical aspects of TEM: Hands-on training in DF and BF imaging, basics of SAED pattern analysis Standard laboratory practices including safety, report writing, and error analysis are also emphasized.
Learning Outcome	Upon completion of this course, the student will be able to: Understand the working principle and applications of various characterization techniques Choose an appropriate technique to characterize various microstructural aspects Characterize the microstructure of various materials by themselves
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Yang Leng; 2nd Ed., Wiley, 2013.
2. Scanning Electron Microscopy and X-Ray Microanalysis: Joseph Goldstein, Eric Lifshin, Charles E. Lyman, David C. Joy, and Patrick Echlin, 3rd Ed., Springer, 2003.

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3		X
PLO4	X	
PLO5		

Course Number	MM2203
Course Credit (L-T-P-C)	3-1-0 (4 AIU Credits)
Course Title	Phase Transformation and Diffusion
Learning Mode	Lecture and Tutorial
Prerequisite	None
Learning Objectives	To understand the importance of phase transformation and diffusion in metallurgy To explain different types of phase transformations commonly encountered in metallic systems and understand the role of diffusion in phase transformations
Course Description	This course provides a foundation for understanding the phenomenological and atomistic kinetic process in materials. It provides a basis for the analysis for the evolution of structure during material processing.
Course Content	Fundamentals of Phase Transformations: Introduction to phase transformations, Types of phase transformations, Free energy and chemical potential, Free energy change estimation for phase transformations. Diffusion in Solids: Fick's laws of diffusion, Solution to Fick's laws, Uphill diffusion and spinodal decomposition, Kirkendall effect. Structure of surfaces and interfaces, Grain boundaries and phase boundaries, Types of interfaces in materials, Energy of surfaces and interfaces, Interface energy and its impact on material properties. Nucleation, Growth Theories, and Kinetics of Phase Transformations: Nucleation theories, Homogeneous nucleation, Heterogeneous nucleation, Growth Theories, thermally activated growth, diffusion-controlled growth, interface controlled growth, coupled growth in eutectoid transformations, discontinuous precipitation, the kinetics of phase transformation, JMAK equation, TTT diagrams, CCT diagrams. Applications and Advanced Phase Transformations: Heat Treatment Processes, Quenching methods: Austempering, Martempering, Annealing, Normalization, Spheroidization, and Homogenization, Martensitic transformations, Characteristics of martensitic transformations, Mechanisms and effects on material properties, Applications of TTT and CCT Diagrams, Phase transformations in Polymers and Ceramics, Specifics of phase transformations in polymers, Specifics of phase transformations in ceramics, Practical applications in materials engineering.
Learning Outcome	Upon completion of this course, the student will be able to: Grasp how the microstructure of the alloys is influenced by phase transformations. Acquire a fundamental understanding thermodynamic and kinetics aspects of phase transformation in metals and alloys. Differentiate the diffusion and diffusionless transformations in selected metallic systems.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Solid State Phase transformation: V. Raghavan, Prentice Hall India, 1987.
2. Phase Transformation in Metals and Alloys, D.A. Porter and K. Easterling, 3rd Ed., CRC Press, 2009.

Reference Books:

1. Physical Metallurgy Principles, Robert E. Reed-Hill, Affiliated East-West Press, 2008.
2. Physical Metallurgy, Vijender Singh, Standard Publishers Distributors, 2010.
3. Introduction to Physical Metallurgy, Sidney H. Avner, Tata McGraw-Hill.

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3	X	

Course Number	MM2204
Course Credit (L-T-P-C)	3-0-3 (4.5 AIU Credits)
Course Title	Mechanical Behaviour of Materials
Learning Mode	Lecture and Practical
Prerequisite	None
Learning Objectives	To understand the behaviour of various materials when subjected to various forces/stresses. To understand the performance of metallic system during their service in terms of fatigue, fracture and creep.
Course Description	The course deals with the behaviour of various materials when they are subjected to various mechanical stresses at ambient and at high temperatures.
Course Content	Dislocation theory: Dislocation motion: jogs, kinks, cross-slip, climb, Peierls stress, stress field of dislocation, forces on dislocations, dislocation multiplication, interaction of dislocations with defects, dislocation dissociation, stacking faults. Plasticity: Elements of plasticity, Von Mises and Tresca criterion, Single Crystal slip, Critically resolved shear stress. Tensile testing (engineering and true), Work-hardening, yield point phenomena, necking. Hardness testing. Mechanical behaviour of polymers and ceramics. Strengthening Mechanisms: Strain hardening, solid solution strengthening, Dispersion hardening, grain size strengthening and Hall-Petch relationship, Precipitate hardening. Fracture: Types of fracture, brittle fracture, Griffith's criteria, fracture in ductile material, fracture toughness, notch effects. Linear elastic fracture mechanics and elasto-plastic fracture mechanics. Ductile to brittle transition. Fatigue: Fatigue testing, S/N curve, low cycle fatigue, structural features, surface effects, mechanisms. Creep: Creep testing, creep curve, creep mechanisms, diffusion creep, dislocation creep, superplasticity.
Learning Outcome	After successfully completing the course, the student will be able to Interpret the deformation behaviour of engineering materials under various loading conditions for various applications. Gain the knowledge of dislocation theory and its correlation to the strengthening mechanisms. Design materials with improved creep, fatigue and fracture properties.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Mechanical Metallurgy: G.E. Dieter, 3rd Ed., McGraw Hill, 2017.

Reference Books:

1. Mechanical Behavior of Materials: Thomas H. Courtney, 2nd Ed., Waveland Press Inc., 2005.
2. Introduction to Dislocations: D. Hull and D.J. Bacon, Butterworth-Heinemann, Elsevier, 2011.
3. Deformation and Fracture Mechanics: R.W. Hertzberg, R.P. Vinci, J.L. Hertzberg, 5th Ed., Wiley, 2012.

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3	X	
PLO4		X

Course Number	MM2204
Course Credit (L-T-P-C)	0-0-3 (1.5 AIU Credits)
Course Title	Mechanical Behaviour of Materials Laboratory
Learning Mode	Practical
Prerequisite	None
Learning Objectives	To understand the behaviour of various materials when subjected to various forces/stresses. To understand the performance of metallic system during their service in terms of fatigue, fracture and creep.
Course Description	The course deals with the behaviour of various materials when they are subjected to various mechanical stresses at ambient and at high temperatures.
Course Content	Tensile/compression test: Introduction to UTM, tensile and compression test on aluminium, copper, steel and polymer, plotting engineering and true stress strain curves, calculate tensile properties, effect of strain rate, strain rate sensitivity. Hardness: Micro and macro-hardness of metal, alloy, ceramic and polymer materials, fracture toughness, nanoindentation, determination of elastic modulus, ductility, Jominy hardenability test. Fracture: fracture surface of metal, ceramic and composites, case study of ductile and brittle fracture. Fatigue and impact test: Rotary bending fatigue testing on steel and aluminium sample, generation of S-N curve, fatigue limit, Charpy V-notch impact test.
Learning Outcome	After successfully completing the course, the student will be able to Interpret the deformation behaviour of engineering materials under various loading conditions for various applications. Gain the knowledge of dislocation theory and its correlation to the strengthening mechanisms. Design materials with improved creep, fatigue and fracture properties.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Mechanical Metallurgy, George E. Dieter, 3rd Ed., McGraw Hill, 2017.
2. Mechanical Behavior of Materials: Thomas H. Courtney, 2nd Ed., Waveland Press, 2000.

Reference Books:

1. Mechanical Properties and Working of Metals and Alloys: Amit Bhaduri, Springer, 2018.

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3	X	
PLO4		X

Course Number	MM2205
Course Credit (L-T-P-C)	3-0-0 (3 credits AIU Credits)
Course Title	Welding and Solidification
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To know about the relevance of solidification of metals and understand the challenges in joining of metals. To understand the thermodynamics and kinetics of the solidification and welding processes.
Course Description	In this course students explore thermodynamics and kinetics of solidification, metal casting, and various welding processes, with a focus on heat transfer and welding defects.
Course Content	Thermodynamics and kinetics of solidification: Thermodynamics of undercooled melts, nucleation process, kinetics of growth, growth mechanisms: continuous growth, stepwise growth. Solidification of pure metals and alloys: - Role of undercooling and Gibbs-Thomson effect on solidification, solutal undercooling, constitutional undercooling, Mullins-Sekerka instability, cellular and dendritic growth, eutectic growth. single crystal growth techniques, zone refining. Metal casting: Pattern and moulds designing, feeding, gating, risering, melting and casting practices, different types of casting: sand casting, die casting, pressure casting, continuous casting, investment casting, casting defects and repair, Ingot structure: chill zone, columnar zone, equiaxed zone. rate of solidification, heat transfer during solidification, Biot number. Welding: Theory and classification of welding, Heat transfer, fluid flow, and solute distribution during welding, submerged arc welding, gas metal arc welding or MIG/MAG welding, TIG welding, resistance welding. Other joining processes, soldering, brazing, diffusion bonding, problems associated with welding of steels and aluminium alloys, defects in welded joints. Solid state welding technique: Friction welding, friction stir welding.
Learning Outcome	After successfully completing the course, the student will be able to Gain insight about casting and solidification. Understand the difficulties of joining metals and come up with solutions. Appreciate the advancements in the solidification and welding of metals from research and industrial perspectives.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Solidification Processing; Fleming, M.C., McGraw-Hill, N.Y., 1974

2. Science and Engineering of Casting Solidification; Stefanescu, D.M., Kluwar Publications, 2002
3. Applied Welding Engineering: Process, Codes and Standard; R.Singh,. Elsevier Inc.,2012
4. Advanced Welding processes, Norrish, J., Woodhead, Woodhead Publishing, 2006
5. Solidification and Casting, Davies, G.J., John Wiley and Sons, 1973

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3	X	

Sl. No.	Subject Code	SEMESTER V	L	T	P	C
1.	MM3101	Thermomechanical Processing of Metallic Materials	3	0	2	4
2.	MM3102	Computational Materials Science	2	1	0	3
3.	MM3103	Engineering Polymers	3	0	2	4
4.	MM3104	Ceramic Science and Technology	3	0	2	4
5.	MM3105	Metallography and Heat Treatment Laboratory	0	0	2	1
6.	XX31PQ	IDE-II	3	0	0	3
TOTAL			14	1	8	19

Course Number	MM3101
Course Credit (L-T-P-C)	3-0-2 (4 AIU Credits)
Course Title	Thermomechanical Processing of Metallic Materials
Learning Mode	Lecture and Practical
Prerequisite	None
Learning Objectives	To understand the dynamic phenomena occurring at deformation of materials at elevated temperatures and their kinetics. To understand different metal forming technologies and their application in controlling the microstructure for specific structural applications.
Course Description	A course exploring the techniques used to modify the microstructure and properties of metals through the combined application of heat and mechanical deformation.
Course Content	Microstructure: Concept of microstructure and micro structural features, Introduction to texture. Crystal plasticity: Deformation in polycrystals, Concept of dislocations and dislocation structures, slip and twinning. Softening mechanisms: (i) Recovery - mechanism and kinetics, structural changes during recovery. Dislocation migration and annihilation, polygonization, subgrain formation. (ii) Recrystallization - mechanism and kinetics, JMAK model. Particle stimulated nucleation. (iii) Grain growth – mechanism and kinetics. Abnormal grain growth. Hot deformation: Dynamic recovery and dynamic recrystallization. Forming technologies: 1. Classification of forming processes 2. Mechanics of metalworking (slab and uniform energy methods) 3. Concept of flow stress and its determination 4. Temperature in metal working (hot and cold working) 5. Strain rate effects 6. Role of friction and residual stresses 7. Concept of workability 8. Microstructure characterization after cold rolling/working, extrusion and forging Case studies: (i) Production of aluminium beverage cans (ii) Microstructure and texture control in electrical steels (iii) Steel for car body applications (iv) Microstructure control via grain boundary engineering
Learning Outcome	After completion of this course, the student will be able to: Understand the deformation behaviour of metallic materials under hot working conditions. Achieve required properties through microstructure control and apply the knowledge for designing materials for various industrial applications.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Book:

1. Thermo-mechanical Processing of Metallic Materials: B. Verlinden, J. Driver, I. Samajdar and R.D. Doherty, Pergamon Materials Science, Elsevier, 2007.

Reference Book:

1. Recrystallization and Related Annealing Phenomena, F.J. Humphreys and M. Hatherly, 2nd Eds, Elsevier, 2004.
2. Metal forming: Mechanics and Metallurgy: W.F. Hosford and R.M. Caddell, 4th Ed., Cambridge University Press, 2014.

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3	X	
PLO4		X
PLO5		X

Course Number	MM3102
Course Credit (L-T-P-C)	2-1-0 (3 (AIU Credits)
Course Title	Computational Materials Science
Learning Mode	Lecture and Tutorial
Prerequisite	None
Learning Objectives	To introduce students to the field of computational materials science. To learn basic numerical methods to solve ordinary differential equations (ODEs) and partial differential equations (PDEs). Role of ODEs and PDEs to solve problems related to materials science and engineering.
Course Description	This course introduces the students to different computer simulations and modelling techniques to investigate the properties and behavior of materials at various length scales.
Course Content	Statistical analysis: p-value, confidence levelling, regression and curve fitting. Introduction to numerical methods: Numerical methods for solving problems. Error estimation, the accuracy of numerical methods. Role of ODEs and PDEs in solving the problems of the physical world Ordinary differential equations: Euler and Runge-Kutta methods, FFT Partial differential equations: classification, elliptic, parabolic, and hyperbolic PDEs, Dirichlet, Neumann, and mixed boundary value problems, Numerical solution of PDEs: relaxation methods for solving elliptic PDEs, explicit and implicit methods, Calculus of variations and variational techniques for solving PDEs, introduction to Finite element method, method of weighted residuals, weak and Galerkin forms Application of numerical methods to solve problems related to materials science: Diffusion (Carburization), spinodal decomposition, grain growth, solidification, Zener pinning. Coding using modern computer languages.
Learning Outcome	Upon completion of this course, the student will be able to: Understand the importance of modelling and simulation in materials engineering. Learn numerical techniques to solve ordinary and partial differential equations. Understand the numerical approaches employed in modelling and simulation in materials science and engineering.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Arfken, G.B., and Weber, H.J., Mathematical Methods for Physicists, Sixth Edition, Academic Press, 2005.
2. W.H., Teukolsky, S.A., Vetterling, W.T., and Flannery, B.P., Numerical Recipes in C/FORTRAN – The art of Scheme of Instruction 2016 Page 278
3. Scientific Computing, Second Edn, Cambridge University Press, 1998.

Reference Books:

1. Lynch, D.R., Numerical Partial Differential Equations for Environmental Scientists and Engineers – A First Practical Course, Springer, New York, 2005

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM3103
Course Credit (L-T-P-C)	3-0-2 (4 credits AIU Credits)
Course Title	Engineering Polymers
Learning Mode	Lecture and Practical
Prerequisite	None
Learning Objectives	To support to comprehend the relationship between structure and properties as well as the uses of engineering polymers. To disseminate information about the characteristics and uses of engineering polymers. To comprehend the purposes of various additives, as well as the kinds, mechanisms, and technical specifications needed for their efficient assessment. Testing products for predicting product performance.
Course Description	This course introduces polymers as engineering materials. This course will also cover the various aspects associated with different engineering polymers such as polymerization processes, morphology, crystallinity, thermal transitions, viscoelasticity, structure-property correlation, compounding and applications.
Course Content	Structure property relationship in polymers: The synthesis, characteristics, and uses of thermoplastic engineering polymers include polyesters -PET, PBT, polyacetals, PC, LCPs, modified polyamides, and polyamides. High temperature resistant thermoplastic engineering polymers, such as PTFE, PCTFE, PVDF, PPO, PPS, polysulphones, PEEK, polyimides, polybenzimidazoles, and aromatic polyamides-Synthesis, properties & applications. Thermoset engineering polymers. Blends of engineering polymers. Additives and engineering polymer compounding: fillers, plasticizers, lubricants, colorants, fire retardants, coupling agents, blowing agents, UV stabilizer, antistatic agents, anti-blocking agents, slip and anti-slip agents, processing aids, antioxidants, stabilizers, lubricants, and toughening agents. Engineering polymer processing- Characterization and testing of engineered polymers.
Learning Outcome	At the end of the course the student will be able to Comprehend the significance of engineering polymers. Acquire fundamental knowledge about characteristics of polymers Select appropriate processing, compounding, and additive methods.to create various engineering polymeric compound grades. Will be able to prepare the test sample for various polymer testing operations. Will be able to measure the polymer properties.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text books:

1. Engineering Plastics Handbook: James M. Margolis, McGraw Hill, 2006.
2. Plastic Materials: J.A. Brydson, 6th Ed., Elsevier, 1995.

References books:

1. Industrial Polymers, Specialty Polymers, and Their Applications: Manas Chanda, Salil K. Roy, CRC Press, 2008.
 2. Specialty Plastics: R.W. Dyson, 2nd Ed., Blackie Academic & Professional, 1988.
- Modern Plastics Handbook: C.A. Harper, McGraw Hill, 2000.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4		X

Course Number	MM3103
Course Credit (L-T-P-C)	(0-0-2) (1 credits AIU Credits)
Course Title	Engineering Polymers Laboratory
Learning Mode	Practical
Prerequisite	
Learning Objectives	To support to comprehend the relationship between structure and properties as well as the uses of engineering polymers. To disseminate information about the characteristics and uses of engineering polymers. To comprehend the purposes of various additives, as well as the kinds, mechanisms, and technical specifications needed for their efficient assessment. To familiarize the students with standard and methodology in preparing various polymers specimen. Testing products for predicting product performance.
Course Description	This course introduces polymers as engineering materials. This course will also cover the various aspects associated with different engineering polymers such as polymerization processes, morphology, crystallinity, thermal transitions, viscoelasticity, structure-property correlation, compounding and applications.
Course Content	Molecular weight studies: Study of gel permeation chromatography (GPC) to determine molecular weight and molecular weight distribution of polymers. Determination of intrinsic viscosity and viscosity average molecular weight of polymers. Spectroscopy studies: Study of Fourier transform infrared spectroscopy (FTIR) for characterization of the structure of the polymers. Microscopy studies: Study of the morphology of polymers using optical microscopy (OM), field emission scanning electron microscopy (FESEM), high resolution transmission electron microscopy (HRTEM) and atomic force microscopy (AFM). Thermal property studies: Study of the thermal properties of polymers using differential scanning calorimetry (DSC), dynamic mechanical analyzer (DMA) and thermogravimetric analyser (TGA). Study of thermal conductivity of polymers. Electrical property studies: Electrical conductivity, impedance, volume/surface resistivity, dielectric strength, arc resistance and comparative tracking Index X-ray diffraction studies: Study of X-Ray scattering and X-Ray diffraction methods to determine crystallinity and orientation in polymers. Mechanical property studies: Tensile strength, compression strength, flexural strength, tear strength, impact strength, hardness and abrasion resistance.
Learning Outcome	At the end of the course the student will be able to Comprehend the significance of engineering polymers. Acquire fundamental knowledge about characteristics of polymers Select appropriate processing, compounding, and additive methods.to create various engineering polymeric compound grades. Will be able to prepare the test sample for various polymer testing operations.

	Will be able to measure the polymer properties.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text books:

1. Vishu Shah, Hand Book of Plastics Technology, John Wiley Interscience Inc., New York.1998.
2. G. C. Ives, J. A. Mead, and M. M. Riley, Hand Book of Plastics Test Methods, I4FFE Books London, 1971.

References books:

1. Handbook of Plastics Analysis, H. Lobo and J. V. Bonilla, Marcel Dekker, 2003.
2. Handbook of polymer Testing Roger Brown, Marcel Dekker Inc, 1999

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4	X	

Course Number	MM3104
Course Credit (L-T-P-C)	3-0-2 (4 AIU Credits)
Course Title	Ceramic Science and Technology
Learning Mode	Lecture and Practical
Prerequisite	None
Learning Objectives	To classify ceramic materials and distinguish them from metals and polymers in relation to their properties and behaviours. To understand the structure of ceramic materials in different length scales and role of processing on structure and microstructure. To understand different industrially relevant processing operations for making of ceramic materials.
Course Description	This course provides an introduction to the diverse world of ceramic materials along with their processing details (with an emphasis on sintering) and selected properties.
Course Content	Introduction to Ceramic Science: Bonding in ceramics, Pauling's rules, Ceramic crystal structures (rocksalt, fluorite, spinel, perovskite), Kröger-Vink notation, defects in ceramic. Defect equilibria, Brouwer diagram. Diffusion in ceramics. Fundamentals of glass science. Ceramic phase diagrams: binary and ternary systems. Physical properties of ceramics (porosity, bulk density, permeability, water absorption, specific gravity) Basics of Ceramic Processing: Synthesis and characterization of ceramic powders. selection of refractory raw materials (natural, synthetic, additives, binders) for specific products. Colloidal processing, rheology of suspensions, ceramic forming methods, and drying. Science of sintering, microstructure development. Properties of ceramics: Fracture behaviour of ceramic materials, The Weibull distribution, Toughening mechanism. Dielectric and piezoelectric ceramics. Applications of ceramics: Traditional ceramics, Abrasives, and high temperature ceramics (refractories and UHTCs). Glass and glass-ceramics.
Learning Outcome	Upon completing of this course, the student will be able to Identify the properties of ceramics with respect to their crystal structure and composition (between oxide and non-oxide). Interpret microstructure property correlation of sintered ceramic materials based on different processing operations. Distinguish different ceramic materials and their utility for diverse industrial applications ranging from traditional to advance ceramic sectors.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Textbooks:

1. Introduction to Ceramics: W.D. Kingery, H.K. Bowen, D.R. Uhlmann, 2nd Ed., Wiley, 1976.
2. Ceramic Processing and Sintering: M.N. Rahaman, Marcel Dekker, 1995
3. Ceramic Materials: Science and Engineering: C. Barry Carter, M. Norton, Springer, 2nd Ed., 2013.

Reference Books:

1. Fundamentals of Ceramics: M.W. Barsoum, McGraw Hill, 1997.
2. Introduction to Ceramics, 2nd Ed., W. David Kingery, H.K. Bowen, Donald R. Uhlmann, Wiley, 1976.
3. A Concise Introduction to Ceramics: G.C. Phillips, VNR Publications, 1991.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4		X

Course Number	MM3104
Course Credit (L-T-P-C)	0-0-2 (1 AIU Credit)
Course Title	Ceramic Science and Technology Laboratory
Learning Mode	Practical
Prerequisite	
Learning Objectives	To classify ceramic materials and distinguish them from metals and polymers in relation to their properties and behaviours. To understand the structure of ceramic materials in different length scales and role of processing on structure and microstructure. To understand different industrially relevant processing operations for making of ceramic materials.
Course Description	This course provides an introduction to the diverse world of ceramic materials along with their processing details (with an emphasis on sintering) and selected properties.
Course Content	Raw materials: Identification, basic characterisation Machineries: Demonstration of basic units, Demonstration of Ceramic products Physical properties: moisture content, Loss on ignition (LOI) of clay, ceramic, Linear and volume shrinkage, Particle size analysis, BET, Gas Pycnometer Powder processing: solid state reactions, synthesis of powders via chemical routes, basic ceramic processing steps (casting, pressing etc) Sintering of ceramics: conventional sintering, obtaining sintering S curve, Grain size analysis Density measurements: Bulk density as per ASTM C20 & C373, Apparent porosity, Archimedes principle, Density of porous ceramic bodies Properties of ceramic: Selected testing for mechanical, thermal, electronic & optical properties
Learning Outcome	Upon completing of this course, the student will be able to Identify the properties of ceramics with respect to their crystal structure and composition (between oxide and non-oxide). Interpret microstructure property correlation of sintered ceramic materials based on different processing operations. Distinguish different ceramic materials and their utility for diverse industrial applications ranging from traditional to advance ceramic sectors.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Introduction to Ceramics: W.D. Kingery, H.K. Bowen, D.R. Uhlmann, 2nd Ed., Wiley, 1976.
2. Ceramic Processing and Sintering: M.N. Rahaman, Marcel Dekker, 1995

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4		X

Course Number	MM3105
Course Credit (L-T-P-C)	0-0-2 (1 AIU Credits)
Course Title	Metallography and Heat Treatment Laboratory
Learning Mode	Practical
Prerequisite	None
Learning Objectives	To understand the metallographic sample preparation of metals. To understand the basic microstructural analysis of metals.
Course Description	This lab course focuses on studying the microstructures of metals and alloys to gain insights into their composition and structural characteristics. Additionally, it explores the various types of heat treatments and their impact on properties of materials.
Course Content	Metallographic sample preparation: Sample cutting, mounting, grinding, dry and wet polishing. Etching: chemical etching, thermal etching. Quantification of microstructures: ASTM grain size number, calculating grain size, mean intercept method, Jefferies method, determining volume fraction of phases Microstructure of ferrous alloys: cast iron, 304 stainless steel, pearlitic steel, annealed and deformed steels, microstructure of quenched and tempered steel. Microstructure of non-ferrous alloys: Aluminium alloy, copper and brass microstructure, deformed and recrystallized microstructure. Surface hardening: Carburizing, nitriding of steel, verification of Harris equation. Hardenability test, Jominy end quench test Precipitation hardening in Al alloy: Homogenization, solutionized, quenching and ageing of AA7075, hardness measurement.
Learning Outcome	Upon completing of this course, the student will be able to Understand the microstructure of ferrous and nonferrous alloys. Distinguish the metallographic techniques, microstructure and hardening process different commercially important metal alloys.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text books:

1. The Principles of Metallographic Laboratory Practice: George L. Khel, McGraw Hill, 1949
2. Physical Metallurgy: V. Raghvan, 3rd Ed., Prentice Hall India, 2015.
3. Steel and its Heat Treatment: K.-E. Thelning, 2nd Ed., Butterworth-Heinemann, Elsevier, 1984.
4. 1984.
5. Heat Treatment: Principles and Techniques: T.V. Rajan, C.P. Sharma, Ashok Sharma, 2nd Ed.,
6. Prentice Hall India, 2010.
7. Heat Treatment of Metals: Vijendra Singh, Standard Publishers Distributors, 2009

	CLO1	CLO2
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PLO1	X	
PLO2		
PLO3	X	
PLO4	X	

Sl. No.	Subject Code	SEMESTER VI	L	T	P	C
1.	MM3201	Techniques of Materials Characterization - II	3	0	3	4.5
2.	MM3202	Corrosion and Corrosion Prevention	3	0	2	4
3.	MM3203	Functional Materials	3	0	0	3
4.	MM3204	Non-ferrous Metals and Alloys	3	0	0	3
5.	MM3205	Capstone Laboratory	0	0	4	2
6.	MM3206	Metals Processing Laboratory	0	0	3	1.5
TOTAL			12	0	12	18

Course Number	MM3201
Course Credit (L-T-P-C)	3-0-3 (4.5 AIU Credits)
Course Title	Techniques of Materials Characterization – II
Learning Mode	Lecture and Practical
Prerequisite	None
Learning Objectives	To understand different aspects materials characterization involving spectroscopy, thermal techniques. To learn about non-destructive characterisation techniques. To obtain hands-on training on different characterization techniques.
Course Description	This course provides an introduction to important thermal and spectroscopic characterization techniques along with the basics of powder characterization and powder processing methods.
Course Content	Spectroscopy: Vibrational spectroscopy, Principles of vibrational spectroscopy, Infrared and Raman activity, Fourier transform infrared spectroscopy, Raman spectroscopy, Micro-Raman. XPS, XRF. UV-visible spectroscopy: Beer's law, Instrumentation, Quantitative analysis. NMR Atomic absorption/ emission spectroscopy: ICP methods for compositional analyses, the difference between ICP-mass spectroscopy and optical/atomic emission methods. Thermal analysis: Instrumentation and principles of techniques used for thermal analysis (DSC, TG-DTA, DMA, EGA), a combined method of thermal analysis and their applications in materials characterization. Particle/grain characterization: Particle size analysis techniques based on light scattering, DLS, gas adsorption (BET), and Gas pycnometer for density measurement. Non-destructive techniques: dye-penetration, ultrasonic, radiography, eddy current, acoustic emission and magnetic particle methods.
Learning Outcome	Upon completion of this course, the student will be able to: Understand the basics of thermal and spectroscopic analysis tools Gain knowledge on the utility of non-destructive characterisation tools and their industrial utility. Gain hands on expertise of thermal, spectroscopic, and non-destructive characterisation techniques.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Textbook:

1. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods; Y. Leng.
2. Fundamentals of Molecular Spectroscopy; C. N. Banwell and E. M. McCash.
3. Surface Analysis: The Principal Techniques; J. C. Vickerman, I. Gilmore.

Reference Books:

1. ASM Handbook: Materials Characterization, ASM International, 2008.
2. Yang Leng: Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd., 2008.
3. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.
8. Prentice Hall India, 2010.
9. Heat Treatment of Metals: Vijendra Singh, Standard Publishers Distributors, 2009

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4		X

Course Number	MM3201
Course Credit (L-T-P-C)	0-0-3 (1.5 AIU Credits)
Course Title	Techniques of Materials Characterization – II Laboratory
Learning Mode	Practical
Prerequisite	None
Learning Objectives	To understand different aspects materials characterization involving spectroscopy, thermal techniques. To learn about non-destructive characterisation techniques. To obtain hands-on training on different characterization techniques.
Course Description	This course provides an introduction to important thermal and spectroscopic characterization techniques along with the basics of powder characterization and powder processing methods.
Course Content	Sample preparation: Powder sample preparation and pellet preparation through die pressing. Powder characterization using BET, gas pycnometer. Thermal properties of materials, identification of materials based on their TG, DSC, and DMA characteristic responses. Sample characterization through Raman and FTIR. Standard laboratory practices including safety, report writing, and error analysis are also emphasized. Non-destructive testing: Radiography, ultrasonic testing.
Learning Outcome	Upon completion of this course, the student will be able to: Understand the basics of thermal and spectroscopic analysis tools Gain knowledge on the utility of non-destructive characterisation tools and their industrial utility. Gain hands on expertise of thermal, spectroscopic, and non-destructive characterisation techniques.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Yang Leng; 2nd Ed., Wiley, 2013.
2. Scanning Electron Microscopy and X-Ray Microanalysis: Joseph Goldstein, Eric Lifshin, Charles E. Lyman, David C. Joy, and Patrick Echlin, 3rd Ed., Springer, 2003.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4		X

Course Number	MM3202
Course Credit (L-T-P-C)	3-0-2 (4 AIU Credits)
Course Title	Corrosion and Corrosion Prevention
Learning Mode	Lecture and Practical
Prerequisite	None
Learning Objectives	To measure and compare the corrosion rates of two different metals/alloys. Hands-on training on electrochemical characterization techniques.
Course Description	The purpose of the course is to provide undergraduate students a scientific knowledge on corrosion engineering along with hands-on training on corrosion measurements and their interpretations.
Course Content	Introduction to terminologies of corrosion experimentation: Oxidation/reduction electrode potential series, listing of half-cell reactions. Practical implications of Nernst equation, standard reference electrode cells, Electrochemical cells, electrolyte, galvanic series, and galvanic corrosion. Corrosion experiments and rate calculations: Preparation of corrosion test samples per ASTM G1. NACE and ASTM standards for measurements of corrosion rates. Salt spray test methods and standards, stress corrosion cracking tests, immersion corrosion testing per ASTM G3. Corrosion rates calculations from Tafel measurements as per the ASTM G102 standard. DC-experimental testing techniques: Potentiodynamic polarization measurement as per ASTM G5, potentiostat, galvanostats, cyclic voltammetry, chrono- amperometry, chrono-potentiometry, potentiodynamic analysis and Tafel extrapolation and linear polarization resistance methods. AC-impedance spectroscopy in corrosion measurements: Assessments related to charge transfer resistance and double layer capacitance from impedance tests. Interpretation of Nyquist and Bode plots. Modelling of impedance data to fit the experimental data. Case studies: Use of AC impedance methods to study the corrosion behaviour of implant alloys.
Learning Outcome	Upon completion of this course, the student will be able to: Correlate the utility of different electrochemical testing techniques. Implement and interpret the data of DC and AC corrosion testing.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Corrosion Science and Technology, By David Talbot, James Talbot, CRC Press, 1998

Reference Books:

1. K.J. Bundy, J. Dillard, R. Luedemann, Use of A.C. impedance methods to study the corrosion behaviour of implant alloys, Biomaterials, Volume 14, Issue 7, 1993 Pages 529-536.
2. A. Harrington, P. van den Driesch, Mechanism and equivalent circuits in electrochemical impedance spectroscopy, Electrochimica Acta, Volume 56, Issue 23, 2011 Pages 8005-8013.

3. ASTM Corrosion Standards and Electrochemical Measurements in Corrosion Testing, ASTM International.

4.

	CLO1	CLO2
PLO1	X	
PLO2		
PLO3	X	
PLO4	X	

Course Number	MM3202
Course Credit (L-T-P-C)	0-0-2 (1 AIU Credits)
Course Title	Corrosion and Corrosion Prevention Laboratory
Learning Mode	Practical
Prerequisite	
Learning Objectives	To measure and compare the corrosion rates of two different metals/alloys. Hands-on training on electrochemical characterization techniques.
Course Description	The purpose of the course is to provide undergraduate students a scientific knowledge on corrosion engineering along with hands-on training on corrosion measurements and their interpretations.
Course Content	Introduction to terminologies of corrosion experimentation: The arrangement of elements according to their electrode potential, or their tendency to corrode. Listing of half-cell reaction voltages. Practical implications of Nernst equation, standard reference electrode cells, Electrochemical cells, electrolyte, galvanic series, galvanic corrosion. Corrosion experiments and rate calculations: Preparing, cleaning and evaluating corrosion test specimens per ASTM G1. NACE and ASTM standards for measurements of corrosion rates. Salt spray test methods and standards, stress corrosion cracking tests, immersion corrosion testing per ASTM G31, Pitting and crevice corrosion resistance of stainless steels. Corrosion rates and related information from electrochemical measurements (Tafel slopes) per ASTM G102. DC-experimental testing techniques: Potentiodynamic anodic polarization measurement per ASTM G5, potentiostat, galvanostats, cyclic voltammetry, chrono- amperometry, chrono-potentiometry, potentiodynamic analysis and Tafel extrapolation and linear polarization resistance methods. AC-impedance spectroscopy in corrosion measurements: Electrochemical impedance spectroscopy (EIS) tests to find out R_p (polarization resistance), C_{dl} (double layer capacitance) & corrosion rate measurement. Interpretation of Nyquist and Bode plots. Modelling of impedance data to fit the experimental data. Case studies: Inter-granular corrosion attack in stainless steels, pitting and crevice corrosion resistance of stainless steels, testing performance of coatings in different circumstances in combination with cathodic protection according to ASTM G42. Use of AC impedance methods to study the corrosion behaviour of implant alloys.
Learning Outcome	Upon completion of this course, the student will be able to: Correlate the utility of different electrochemical testing techniques. Implement and interpret the data of DC and AC corrosion testing.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Corrosion Science and Technology, By David Talbot, James Talbot, CRC Press, 1998

Reference Books:

1. K.J. Bundy, J. Dillard, R. Luedemann, Use of A.C. impedance methods to study the corrosion behaviour of implant alloys, *Biomaterials*, Volume 14, Issue 7, 1993 Pages 529-536.
2. A. Harrington, P. van den Driesch, Mechanism and equivalent circuits in electrochemical impedance spectroscopy, *Electrochimica Acta*, Volume 56, Issue 23, 2011 Pages 8005-8013.
3. ASTM Corrosion Standards and Electrochemical Measurements in Corrosion Testing, ASTM International.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4	X	

Course Number	MM3203
Course Credit (L-T-P-C)	3-0-0 (3 AIU Credits)
Course Title	Functional Materials
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To identify various ranges of functions displayed by materials and correlation of the same with respect to their properties. To understand the fundamental reasons due to which this variety of properties is possible for different materials. To evaluate the efficacy of a particular material with respect to emerging and conventional industrial applications.
Course Description	This course provides general overview on the origins of functional properties of materials, their wide varieties and their usability in different advanced technological applications.
Course Content	Free Electron Theory of Metals: Band theory, classification of materials based on band theory viz. conductors, conductors-classification and properties, factors affecting conductivity/resistivity of conductors, various conducting materials: composition, properties and applications. Resistors: Materials used for heating elements viz. nichrome, kanthal, silicon carbide and molybdenum, their composition, properties and applications Semiconductors: Intrinsic and extrinsic semi-conductors, II-VI, III-V and IV-IV group semiconductors, effects of doping. Magnetic materials: Sources of magnetism-orbital and spin motion of electron, types of magnetism: Dia-, para-, ferro-, ferri- and antiferro-magnetism, domain theory, types of magnetic materials: soft and hard magnetic materials and ferrites. GMR. Ferro-electric, Piezo-electric and Dielectric materials: Principle, materials and their applications; Ferroelectric ceramic materials, Basic Ceramic Dielectric formulation for capacitors. Multi-Layer Capacitors. Super conductivity: BCS theory, Meissner effect, materials, Type I and II superconductors.
Learning Outcome	Upon completing of this course, the student will be able to Identify the properties of metals, ceramics and polymers in relation to different functional properties Understand the fundamental reasons which enable a particular material to display a particular function Classify and distinguish different types of functional properties and correlate the same with relevant industrial applications
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Introduction to the Electronic Properties of Materials: David C. Jiles, 2nd Ed., CRC Press, 2001.
2. Electronic Materials Science: Eugene A. Irene, Wiley, 2005.

3. An Introduction to Electronic Materials for Engineers: Zhengwei Li, Nigel M. Sammes, 2nd Ed., World Scientific Publishing Company Pvt. Ltd., 2011.

Reference Books:

1. Electronic Materials and Devices: David K. Ferry, Jonathan P. Bird, Wiley, 2001.
 2. Introduction to Magnetism and Magnetic Materials: David Jiles, 3rd Ed., CRC Press, 2015.
- Electroceramics: Materials, Properties, Applications: A.J. Moulson, J.M. Herbert, Wiley, 2003.

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3	X	

Course Number	MM3204
Course Credit (L-T-P-C)	3-0-0 (3 AIU Credits)
Course Title	Non-ferrous Metals and Alloys
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the different types of nonferrous alloys. To understand the physical and mechanical characteristics of nonferrous alloys.
Course Description	A specialized course covering the properties, applications, and processing of non-ferrous alloys, including aluminum, copper, magnesium, titanium, nickel, cobalt, and refractory metals.
Course Content	Non-ferrous alloys: (i) Classification of aluminium alloys, heat treatable and non-heat-treatable alloys, tempers, grain refiners, phase diagram, heat treatment, properties and applications. (ii) Copper alloys, copper-zinc phase diagram, brass and bronze. Properties and applications (iii) Magnesium and its alloys, properties and applications, corrosion behavior. (iv) Titanium alloys, alpha, beta, alpha-beta alloys, processing characteristics, properties and applications. (v) Nickel and cobalt based alloys and superalloys, properties and applications (vi) Refractory metals-based alloys, intermetallics. Case studies: Materials design and selection for (i) Automobile engine, (ii) turbine blades and (iii) bio-implants.
Learning Outcome	Upon completion of this course, the student will be able to: Gain in-depth knowledge of non-ferrous alloys, their properties and applications. Understand the mechanical processing, heat treatments and corrosion of various nonferrous alloys.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Physical Metallurgy and Advanced Materials: R.E. Smallman, A.H.W. Ngan, 7th Ed., Butterworth Heinemann, Elsevier, 2007.
2. Physical Metallurgy: Principles and Design: G.N. Haidemenopoulos, CRC Press, 2018.

Reference Books:

1. Concepts in Physical Metallurgy: A. Lavakumar, Morgan and Claypool Publishers, IOP Science, 2017
2. Nonferrous Physical Metallurgy: Robert Raudebaugh, Literary Licensing, 2013.
3. Nickel, Cobalt and their alloys: Joseph R. Davis, ASM International, 2000.

	CLO1	CLO2
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PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM3205
Course Credit (L-T-P-C)	0-0-4 (2 AIU Credits)
Course Title	Capstone Laboratory
Learning Mode	Practical
Prerequisite	None
Learning Objectives	To allow students to implement and test their designs, integrating theoretical knowledge with practical application. To enhance hands-on learning, reinforce theoretical concepts, and promote creativity.
Course Description	Capstone Laboratory course is designed to integrate and apply knowledge and skills acquired throughout a student's academic program in the Metallurgical and Materials Engineering department.
Course Content	Capstone projects to be decided by the course instructor Few suggested projects are: Environmental Barrier Coatings for Gas Turbine Engines Finite Element Analysis of Metal Forming Metal Extraction from Ores obtained from Indian Mines Development of Aluminium alloys and Study the Effect of Heat Treatment on Properties Ceramic Musical Instrument Making through Traditional Techniques Development of Metal Matrix Composite for High Temperature Application Piezo sensor for Determination of Force Involved in Cricket Shot Demonstrations of few polymerization techniques for synthesis of porous polymers/ smart polymers/ self-healing polymers
Learning Outcome	After doing the laboratory course the student will be able to Apply the knowledge acquired from MME program in real-life situation. Able to understand theoretical concepts more effectively and come up with new ideas.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

Reference Books:

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4	X	

Course Number	MM3206
Course Credit (L-T-P-C)	0-0-3 (1.5 AIU Credits)
Course Title	Metals Processing Laboratory
Learning Mode	Practical
Prerequisite	None
Learning Objectives	To learn various metal casting techniques and identify common casting defects, microstructure of casting. To learn various metal forming techniques including welding. To observe the microstructural changes imparted by various processing techniques.
Course Description	The course covers the ingot casting, casting defects, solidification microstructures, recrystallization, the shape memory effect in Nitinol, and various welding techniques.
Course Content	Ingot casting: Casting design, Melting furnaces, die casting of metal and alloy, shape casting, moiling, refining and pouring. Defects in castings: Physical inspection, hot tear cracks, pores, voids. Solidification microstructures: Dendritic microstructure, grain structure, homogenization, alloying element addition during casting. Recrystallization and annealing: recrystallization in copper and aluminium alloys. Shape memory effect: Reversible phase transition in Nitinol. Welding: arc welding, soldering, friction stir welding, welding microstructures,
Learning Outcome	After doing the laboratory course the student will be able to Understand the different metal casting methods for various applications. Understand various secondary processing techniques including metal forming and joining. Understand the effect of various processes on microstructural evolution.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Heat Treatment: Principles and Techniques: T.V. Rajan, C.P. Sharma, Ashok Sharma, 2nd Ed., Prentice Hall India, 2010.
2. Heat Treatment of Metals: J.L. Smith, G.M. Russel, S.C. Bhatia, Vol. 1, CBS Publishers, 2008.
3. Heat Treatment of Metals: Vijendra Singh, Standard Publishers Distributors, 2009.

Reference Books:

1. Heat treatment of Steel: Hardening, Tempering and Case Hardening: H.R. Badger, Forgotten Books, 2018.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4	X	

Sl. No.	Subject Code	SEMESTER VII	L	T	P	C
1.	MM41XX	Departmental Elective - I	3	0	0	3
2.	MM41XX	Departmental Elective - II	3	0	0	3
3.	HS41XX	HSS Elective - II	3	0	0	3
4.	XX41PQ	IDE-III	3	0	0	3
5.	MM4198	Summer Internship*	0	0	12	3
6.	MM4199	Project – I	0	0	12	6
TOTAL			12	0	24	21

Sl. No.	Subject Code	Departmental Elective - I	L	T	P	C
1.	MM4101	Environmental Sustainability and Industrial Safety	3	0	0	3
2.	MM4102	Glass Science and Technology	3	0	0	3
3.	MM4103	Semiconductor Materials and Devices	3	0	0	3

Course Number	MM4101
Course Credit (L-T-P-C)	3-0-0 (3 AIU Credits)
Course Title	Environmental Sustainability and Industrial Safety
Learning Mode	Lecture
Prerequisite	
Learning Objectives	The ability to select and use the discipline's knowledge, methods, and cutting-edge instruments to domains widely construed as safety, health, and environmental engineering and technology, as well as fire prevention. To support students in comprehending the core ideas of sustainable development, including strong and weak sustainability, natural capitalism, steady state, and green economies, as well as equality within and between generations and economic, social, and environmental sustainability
Course Description	This course covers essential topics such as environmental regulations, sustainable development goals in mining, ceramic, polymer and metallurgy industries and safety measures in industrial environments.
Course Content	Introduction: Sustainable Development Goals (SDGs) and their concept, environmental concerns in mining, metallurgy, ceramics, and polymers operational standards, safeguarding and managing resources. Industrial waste in materials industries: Industrial wastes from metals, ceramics, plastics and rubber based industries - Identification, characterization and classification. Handling, transportation and storage. Disposal: equipment and processing methods; legal procedures. Recover, recycle, and recycle. Impact of beneficiation process. Industrial safety: Concept of safety, safety by design, safety inspection, accident prevention, Heinrich theory of accident prevention, cost of accident, safety performance monitoring. Safety against fire, chemicals, and acids: detection, prevention, and protection. Health hazards: Common industrial hazards and remedies, engineering controls and personal protective controls, hazard identification and risk assessment- FMEA and HAZOP, QRA. Temporary and cumulative effects in Occupation diseases - silicosis, asbestosis, pneumoconiosis, aluminosis, gas poisoning. Game theory approach to deal pollution. Safety management: Safety guidelines and procedures in the materials sector. Case studies on the mining, blast furnace, iron and steel industries, foundries, hot and cold processing of metals, and blast furnaces. Handling powders and raw ingredients for ceramics. Issues about the health and safety of raw materials used in sanitary napkins, glass, refractory, and cement. Prevention and awareness of associated hazards and illnesses.

Learning Outcome	At the end of the course the student will be able to Apply comprehension of engineering principles to identify, evaluate, and control occupational hazards. Recognize and promise to abide by legislative rules and regulations, as well as contractual duties related to sustainable development, in order to protect occupational health, safety, and the environment in the organization.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. M.H. Fulekar, B. Pathak, R.K. Kale, Environment and sustainable development, Springer, 2014.
2. D. Petersen, Techniques for safety management - A systems approach, ASSE 1998.

Reference Books:

1. S.P. Mahajan, Pollution control in process industries, Tata McGraw Hill Publishing Company, New Delhi, 1993.
2. J. Nagaraj, Industrial safety and pollution control handbook, National safety council, 1992.
3. Michael Karmis, Mine Health and Safety Management, SME, Littleton Co., 2001.
4. N.V. Krishnan, Safety in Industry, Jaico Publishing House, 1996, Mine Health and Safety Management SME, Littleton, CO, USA, 2001.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4		
PLO5	X	

Course Number	MM4102
Course Credit (L-T-P-C)	3-0-0 (3 AIU Credits)
Course Title	Glass Science and Technology
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To know about the critical role glass plays in day-to-day life and to understand the state-of-art modern and updated Industrial glass production techniques To understand the thermodynamics and kinetics of glass formation and how it influences the structure and property
Course Description	The course explores the fundamental principles underlying glass behaviour and their applications in various industries
Course Content	Glass Science: Nature of the glassy state, Glass formation and the glass transition, Kinetic and thermodynamic criteria for glass formation, glass former, modifier and Intermediate, TTT diagram, phase diagrams in glass manufacture, structural, Thermodynamic, and Kinetic effects on T_g, viscosity of glass, Bridging and Non-Bridging Oxygen. Types of glasses and their chemical compositions, Physical properties of glasses, density, refractive index, thermal expansion and thermal stresses, thermal endurance of glass, toughening of glasses, strength and fracture behavior of glass and its articles, effect of temperature and composition on the physical properties of glasses, durability and corrosion behavior, colored glass. Glass Technology: Glass-making raw materials, addition of cullet to the batch, glass-batch formulation, batch materials handling equipment, reactions amongst the constituents of glass, design of glass tank furnace. temperature modelling for appropriate refractory selection, thermal currents, and flow pattern in the glass tank furnace, refining of glass, defects in glass, bubbles and seeds, cords, stresses, and color inhomogeneity and their remedies, annealing of glasses, measurement of stress/ strain in glass, Float glass, Container glass, Glass Fibre, and fiberglass. Glass-ceramics: Nucleation and crystal growth in glasses, nucleation through micro miscibility, nucleating agents, properties and applications of glass-ceramics.
Learning Outcome	Upon completion of this course, the student will be: Familiar with different types of glass and its application Familiar with industrial glass making and able to solve industrial problems regarding glass processing Able to understand the properties of glass and how it is different from its crystalline counterpart
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Glass Science and Technology, D.R. Uhlmann, N.J. Kredl (ed), Vol. 1&2, Academic Press, 1990.
2. Chemistry of Glasses: Amal Paul, Chapman Hall, 1990.

Reference Books:

1. Fundamentals of Ceramics: M.W. Barsoum, McGraw Hill, 1997.
2. Introduction to Ceramics, 2nd Ed., W. David Kingery, H.K. Bowen, Donald R. Uhlmann, Wiley, 1976.
3. Hand book of Glass Manufacture: F.V.Tooley, Vol 1 & 2, Ashlee Pub. Co, 1984.

	CLO1	CLO2
PLO1		X
PLO2		
PLO3	X	X

Course Number	MM4103
Course Credit (L-T-P-C)	3-0-0 (3 AIU Credits)
Course Title	Semiconductor Materials and Devices
Learning Mode	Lecture
Prerequisite	
Learning Objectives	To discuss the working and applications of basic semiconductor devices To impart a fundamental knowledge of device fabrication relevant to the semiconductor industry. To enable the students to understand working principle of semiconductor devices such as transistors, diodes, solar cells, and light-emitting devices.
Course Description	This course provides students with foundational knowledge of semiconductor devices, covering essential principles and advanced semiconductor physics. After completion of the course, students will have understanding of semiconductor technology fundamentals, designed and analysed semiconductor devices.
Course Content	Fundamental of Semiconductors: Energy band theory, Sommerfield free electron theory for metals, Brillouin Zone Theory, density of states, Quasi-Fermi levels, Maxwell-Boltzmann distribution, Fermi-Dirac statistics, intrinsic semiconductor, n-type/p-type semiconductor, transport phenomenon of charge carriers, Energy bands in solids, band structure, band diagram of few important semiconductors (Si, Ge, GaAs, GaN), engineering of doping, surface energy of solids, effective mass, Brillouin zone, direct and indirect gaps semiconductor and photovoltaic effect. Fabrication of Semiconductors and devices: Production of single crystal of semiconducting materials, Semiconductor Grade Silicon, metallurgical grade silicon, Lithography, DC/RF magnetron sputtering. Devices and characterizations: Heterostructure p-n junctions, Schottky junctions, Ohmic contacts: Metal-semiconductor junctions, Schottky and Ohmic contacts, Metal-Semiconductor contacts, Metal-insulator-semiconductor structures, tunnel diodes, Gunneffect, p-i-n structures, Zener diode, Bipolar transistors, principle of operation of MOSFETs, characteristics of MOSFET, source-drain/transfer characteristics of MOSFET, introduction to JFETs, MESFETs, and MODFETs. carrier statistics under illumination condition, generation and recombination of carriers, emitting diodes (LED), LEDs, laser-diodes and solar cells, Current-voltage characteristics, capacitance-voltage (CV) and impedance measurements.
Learning Outcome	Upon completion of this course, the student will be able to: Grasp the basics concepts of semiconductor materials such as the energy bands, band gap, charge carrier concentration, transport phenomenon of charge carriers. Describe the fabrication of semiconductors devices Demonstrate the applications of various semiconducting devices such as p-n and Schottky junctions, BJTs and FETs, LEDs and solar cells

Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.
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Text Books:

1. Semiconductor Devices: Physics and Technology Hardcover – by Simon M. Sze (Author), Ming-Kwei Lee, 2012.
2. An Introduction to Semiconductor Devices- D. Neamen, McGraw-Hill Education, 2005.
3. Physics of Semiconductor Devices -S.M. Sze and K. K. Ng, Wiley- Interscience, 3rd edition, 2006.

Reference Books:

1. Semiconductor Physics: An Introduction. K. Seeger, Springer-Verlag, Berlin, 9th Ed., 2004.
2. Electronic Materials and Devices: David K. Ferry, Jonathan P. Bird, Wiley, 2001.
3. Introduction to the Electronic Properties of Materials: David C. Jiles, 2nd Ed., CRC Press, 2001.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Sl. No.	Subject Code	Departmental Elective - II	L	T	P	C
1.	MM4104	Thin Films	3	0	0	3
2.	MM4105	Heat Treatment of Steel	3	0	0	3
3.	MM4106	Creep, Fatigue and Fracture	3	0	0	3

Course Number	MM4104
Course Credit (L-T-P-C)	3-0-0 (3 AIU Credits)
Course Title	Thin Films
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	Understand about the various physical and chemical deposition methods Understand and analyse the characteristics of thin films using different instrumentation technique. Able to understand different types of nucleation theories, growth mechanisms of thin films.
Course Description	This course provides fundamentals of synthesis, nucleation, growth of thin films along with their suitability of applications in diverse technological fields.
Course Content	Basics of surface: Concept of Surface Energy, Surface Thermodynamics, Surface Tension and Surface Energy, Broken Bond Model for Surface Energy of Crystalline Solids (BCC and FCC), Mechanisms for Reduction of Surface Energies, Surface Relaxation, Restructuring and Adsorption. Vacuum components for thin films: Importance of High Vacuum for making thin films, Details of Vacuum Pumps (e.g. Rotary Turbo-molecular and Diffusion Pump), Pressure Gauge regular maintenance for vacuum conditions. Thin film deposition techniques: Physical vapour deposition methods (Glow discharge, RF, Magnetron sputtering), Evaporation (Vacuum, electron beam, ion beam evaporation), Chemical Vapour Deposition Methods (Metal-Organic, Plasma Enhanced, Photochemical etc.), Plasma Technology for Thin Films, Molecular Beam Epitaxy atomic layer deposition. Solution based chemical Techniques: Spray pyrolysis, Electrodeposition, Electroless deposition and plating for large area industrial coating, Sol-gel (spin coating and dip coating) and Langmuir Blodgett techniques for polymer and soft molecules. Fundamental physical and chemical processes: Nucleation and Growth of Thin Films, Structure Zone Model, 3-D island layer by layer growth, thin film Microstructure, orientation and their influence on final properties. Characterization of thin films: In situ characterizations, techniques for physical and structural characterization (thickness, phase, composition, morphology etc.), Highlights of measurements for various functional and chemical properties of thin films. Applications of thin films: Hard Mechanical Thin Coatings, Thin films for Transistors and Semiconductors, Applications of Organic Thin Films.

Learning Outcome	Upon completing of this course, the student will be able to: Identify various techniques of thin film depositions Classify and distinguish different types of thin film and their properties with relevant industrial applications Understand the nucleation and growth of various thin films during processing.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Milton Ohring, The Materials Science of Thin Films, Academic Press-Sanden, 1992
2. Vacuum deposition of thin films, L. Holland, Chapman and Hall.
3. Thin films phenomena, K.L. Chopra, McGraw Hill, Yew York.

Reference Books:

1. Thin Film Materials: Stress, Defect Formation and Surface Evolution, L. B. Freund, S. Suresh, Cambridge University Press, 2004
2. Thin Film Processes II, Werner Kern, editor: John Vossen, Academic Press, 2012
3. Thin-Film Deposition: Principles and Practice, Donald L. Smith, McGraw Hill Professional, 1995

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM4105
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Heat Treatment of Metals and Alloys Steel
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the time-temperature sequence for altering the microstructure with/without application of stress To understand the engineering of various heat treatment processes and their impact on material properties.
Course Description	A course exploring heat treatment processes and phase transformations. It also covers thermo-mechanical treatments, case hardening techniques, and the impact of heat treatment on engineering steels.
Course Content	Introduction to heat treatment: Objective of heat treatment; thermodynamics of phase transformation; Iron carbon phase diagram and their limitations; Austenitic, bainitic and martensitic transformations. Various types of heat treatment furnaces; TTT Diagram: types and application of TTT Diagrams (Austempering, Patenting and Martempering); CCT Diagram; Annealing (stress-relieving annealing, spheroidization, homogenising, etc.), Normalising, Hardening (objective, methods, quenching mediums, internal stresses and austenitizing temperature, defects in the process), Tempering (objective, stages, effects of addition of carbon and other alloying elements). Tempering of numerous alloy steels. Thermo-mechanical treatment of steels: Principles, Ausforming; Isoforming; Embrittlement during tempering, hardenability and factors affecting the properties. Hardening (case and surface): Nitriding, Carburising, and Carbonitriding, Laser hardening, and Induction hardening. Engineering steels: Heat treatment and their effect on industrial steels including stainless steels, tool steels, maraging steels, dual phase steels, bearing steels, spring, and HSLA steel.
Learning Outcome	Upon completion of the course, the student will be able to: Appreciate the guiding factor of heat treatment which would influence the properties in a desired way Acquire insights into the relationship among process, property and microstructure.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Heat Treatment of Metals: B. Zakharov, CBS Publishers, 1998.
2. Principles of Heat Treatment of Steels, F.M.B. Fernandes and T. Ericsson, ASM Handbook, 1991.
3. Heat Treatment of Metals: Vijendra Singh, Standard Publishers Distributors, 2009.

Reference Books:

1. Principles of the Heat Treatment of Plain Carbon and Low Alloy Steels: C.R. Brooks, ASM International, 1996.
2. Steels: Processing, Structure and Performance: G. Krauss, 2nd Ed., ASM International, 2015.
3. The Physical Metallurgy of Steels: W.C. Leslie, McGraw-Hill, 1981.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM416
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Creep, Fatigue and Fracture
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	Gain a thorough understanding of creep, fatigue, and fracture mechanisms in engineering materials. To understand and predict how materials fail under various loading conditions and the deformation behaviour of metallic materials at high temperatures.
Course Description	The course is designed for students to deepen their understanding of deformation and fracture behavior of metals under different strain rate conditions.
Course Content	Creep: Stress-strain curve, concept of homologous temperature, effect of temperature on dislocation motion. Creep curve, structural changes during creep, constitutive equations. Mechanism of creep deformation, dislocation creep, diffusion creep. Deformation mechanism maps, superplasticity in metals and ceramics, grain boundary sliding, rupture Fatigue: Cyclic stress-strain, low cycle fatigue, Coffin-Manson relation, S-N curve, stress intensity factor, notch sensitivity, fatigue crack initiation mechanism, Paris law, factors affecting fatigue life, thermal fatigue, fatigue protection methods, fretting. Creep-fatigue interaction. Case studies. Fracture: basic models of fracture, Griffith theory, stress concentration factor, ductile fracture, brittle fracture, ductile to brittle transition, modes of fracture, hydrogen embrittlement. Fracture in structural and bio-implant components, fracture under rapid loading rates. Stress corrosion cracking, Fractography. Case studies.
Learning Outcome	Upon completion of course the students will be able to Differentiate between creep, fatigue, and fracture and explain the mechanisms by which they occur in different materials. Design components that consider creep, fatigue, and fracture resistance for safe and reliable operation.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Mechanical Behavior of Materials: Thomas H. Courtney, 2nd Ed., Waveland Press Inc., 2005.
2. Mechanical Metallurgy: G.E. Dieter, 3rd Ed., McGraw Hill, 2017.
3. Deformation and Fracture Mechanics: R.W. Hertzberg, R.P. Vinci, J.L. Hertzberg, 5th Ed., Wiley, 2012.

Reference Books:

1. Metal Fatigue in Engineering: R.I. Stephens, A. Fatemi, R.R. Stephens, H.O. Fuchs, 2nd Ed., Wiley, 2000.
2. Creep of Engineering Materials: I. Finnie, W. R. Heller, McGraw Hill, 1999.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Sl. No.	Subject Code	SEMESTER VIII	L	T	P	C
1.	MM42XX	Departmental Elective - III	3	0	0	3
2.	MM42XX	Departmental Elective - IV	3	0	0	3
3.	MM42XX	Departmental Elective - V	3	0	0	3
4.	MM4299	Project – II	0	0	16	8
TOTAL			9	0	16	17
GRAND TOTAL (Semester I to VIII)			166			

Sl. No.	Subject Code	Departmental Elective - III	L	T	P	C
1.	MM4201	Smart Polymers	3	0	0	3
2.	MM4202	Energy Materials	3	0	0	3

Course Number	MM4201
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Smart Polymers
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To introduce the basic concepts of synthesis & processing of smart polymers To develop an understanding of different types and properties of smart polymers To impart knowledge of smart polymers applications
Course Description	This course discusses the ability of certain classes of polymers to behave as smart polymers. This course will cover the ability of smart polymers to undergo a dramatic reversible physical or chemical change when an external stimulus is applied. The course will also include the synthesis, characterization, properties and applications of various smart polymers.
Course Content	Introduction: Overview, types and applications of smart polymer. Temperature-responsive polymers: Basic concepts of temperature-responsive polymers in aqueous solution, Key forms of temperature-responsive polymers in aqueous solution, selected programs of thermo-responsive polymers. pH-responsive polymers: Key varieties and characteristics of pH-responsive polymers, various architectures of pH-responsive polymers, Synthesis of pH-responsive polymers, Different methodologies for the preparation of pH-responsive polymers and Applications. Photo-responsive polymers: Key types and properties of photo-responsive polymers Chromophores and their light-induced molecular response, and Applications. Magnetically responsive polymer gels and elastomers: synthesis of magnetically responsive polymer gels and elastomeric materials, Magnetic properties of filler-loaded polymers, Elastic behaviour of magnetic gels and elastomers, The swelling equilibrium under a uniform magnetic field, Kinetics of shape change, Polymer gels in a non-uniform electric or magnetic field and Applications. Enzyme-responsive polymers: Enzyme-responsive materials: rationale, definition and history, Preparation of enzyme-responsive polymers, Characterisation of enzyme-responsive polymers, Key varieties and characteristics of enzyme-responsive polymers and Applications. Shape memory polymers: Characterizing shape memory effects in polymeric materials, Categorizing shape memory polymers based on their stimulus type and polymer structure, Applications. Smart polymer hydrogels: Synthesis, key categories, characteristics, and uses for hydrogels made of smart polymers.

	Self-healing polymer systems: Different forms of self-healing, Self-healing and recovery of functionality in materials. Applications of smart polymers: Drug delivery using smart polymer nanocarriers, smart polymers in medical equipment for minimally invasive surgery, diagnosis, and other uses, Smart polymers for textile applications, for food packaging applications, for optical data storage and for bio-separation and other biotechnology applications.
Learning Outcome	Upon completion of this course, the students will be conversant with Fundamentals and processing of smart polymers. Environmentally responsive polymers (i.e. temperature, pH, light etc.), Self-healing polymers, Shape memory polymers, Enzyme-responsive polymers, magnetically responsive polymer. Application of smart polymers (i.e. drug delivery, medical devices, bio-technology, textile, optical storage).
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Maria Rosa Aguilar, Julio San Román, Smart Polymers and Their Applications, Woodhead Publishing Limited/Elsevier, 2019.
2. José Miguel García, Félix Clemente García, José Antonio Reglero Ruiz, Saúl Vallejos and Miriam Trigo-López, Smart Polymers Principles and Applications, De Gruyter, 2022.

Reference Books:

1. Asit Baran Samui, Smart Polymers Basics and Applications, Taylor and Francis Group, 2022.
2. Igor Galaev, Bo Mattiasson, Smart Polymers Applications in Biotechnology and Biomedicine, Routledge/ Taylor and Francis Group, 2019.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM4202
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Energy Materials
Learning Mode	Lecture
Prerequisite	
Learning Objectives	To understand the challenges and issues related to energy-efficient technology. Describes how advanced materials make possible efficient energy harvesting, energy conversion and energy storage technologies. Explain energy-related material issues including design, synthesis, characterization, and performance for energy device applications. Discuss materials enabling energy-efficient transportation and housing.
Course Description	This course offers a materials science perspective on energy efficient technology. Students will study advanced materials for energy harvesting (e.g., solar cells, wind energy), energy conversion (e.g., fuel cells, LEDs), and energy storage (e.g., batteries, hydrogen storage).
Course Content	Introduction: Optoelectronic, Photovoltaic technologies, Energy Efficient Lighting Energy harvesting technologies/materials: organic and inorganic solar cells, nuclear materials, material for wind energy and thermoelectric Energy conversion technologies/devices: e.g., polymer and solid oxide fuel cells, light emitting diodes, engines, and turbines Energy storage technologies: batteries, introduction to electrochemical energy storage and conversion, lithium ion batteries, basic components in Lithium – ion batteries: electrodes, electrolytes, and current collectors, characteristics of commercial lithium ion cells, Sodium ion rechargeable cell, introduction to battery pack design, advanced materials and technologies for supercapacitors, Li – Air batteries, Li – Sulphur batteries, rare-earth Li resources and recycling of Li ion battery, Other types of batteries, hydrogen storage, phase change materials. Supercapacitor Energy-efficient materials: transportation, housing. Materials selection
Learning Outcome	Upon completion of this course, the student will be able to: Understand theories for optoelectronics, photovoltaics, electrocatalysis and batteries. Demonstrate knowledge of materials design, synthesis, and modification for energy related applications. Utilize various materials engineering techniques to enhance the performance of energy applications. Demonstrate the structure/composition-performance relationship for energy materials.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Handbook of Photovoltaics Science and Technology, By Antonio Luque and Steven Hegedus

2. Physics of solar cells: from basic principles to advanced concepts, By Peter Würfel and Uli Würfel

Reference Books:

1. Organic photovoltaics: materials, device physics, and manufacturing technologies, By Christoph J. Brabec, Vladimir Dyakonov, Ullrich Scherf
2. Principles of Solar Cells, LEDs and Diodes: The Role of the PN Junction, By Adrian Kitai

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	
PLO4		
PLO5	X	

Sl. No.	Subject Code	Departmental Elective - IV	L	T	P	C
1.	MM4203	Electroceramics	3	0	0	3
2.	MM4204	Biomaterials	3	0	0	3

Course Number	MM4203
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Electroceramics
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To demonstrate the fundamentals of functional (electronic, magnetic, optical, dielectric etc.) To illustrate process, structure, property correlations of wide range of functional ceramic materials.
Course Description	This course provides general overview on the origins of functional properties of ceramics, their wide varieties and their usability in different advanced technological applications.
Course Content	Ceramic Capacitors: Multi-layer ceramic capacitors, Importance of BaTiO₃ as a capacitor material, Improvement of dielectric constant, effect of doping. Electronic and Ionic conducting ceramics: Highly conducting ceramics, non-stoichiometric and valence-controlled semiconductors. Grain boundaries effects, NTC and PTC thermistors, Superionic ceramic conductors (AgI, β-Alumina). Piezoelectric, Ferroelectric and Electro-optic Ceramics: Ferroelectric ceramic materials, chronology of ferroelectric ceramics, ferroelectric hysteresis and poling, Relaxor ferroelectrics, General characteristics of piezoelectric materials, Piezoelectric constants. Electro optic effect, linear, quadratic and memory devices, importance of morphotropic phase boundary, Pyroelectric Materials, Electro-optic Ceramics. Magnetic Ceramics: Soft and hard ferrites, their applications. Ni-Zn ferrites, Mn-Zn ferrites, mixed garnets and Hexagonal Ferrites. Effect of composition, processing and microstructure on the magnetic properties. Processing and applications of magnetic ceramics.
Learning Outcome	Classify various classes of electroceramic materials and describe their structure and properties Relate the phase, chemical composition and microstructure of electroceramics to the particular conductive, dielectric, ferroelectric, piezoelectric and pyroelectric, electro-optic and magnetic properties.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Electroceramics: Materials, Properties, Applications: A.J. Moulson and J.M. Herbert, 2nd Ed., Chapman & Hall, Springer, 2003.
2. Fundamentals of Ceramics: Michel W. Barsoum, McGraw Hill, 1997.
3. Ceramic Materials for Electronics: R.C. Buchanan (ed.), Marcel Dekker, 1991.
4. Electronic Ceramics: L.M. Levison (ed.), Marcel Dekker, 1988.

Reference Books:

1. Ferroelectric Materials and Their Applications: Y.H. Xu, North-Holland, Elsevier, 1991.
2. Piezoelectric Ceramics: Principles and Applications: APC International, Ltd, 2002.
3. Ferroelectric Devices: Kenji Uchino, Marcel Dekker, 2000.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM4204
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Biomaterials
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To identify the major types of materials that are used in the body and their major modes of failure and apply material property fundamentals to analyze the performance of a material in vivo and translate material properties from test data to material performance. To understand common use of biomaterials as metals, ceramics and polymers and its chemical structure, properties, and morphology. To understand the interaction between biomaterial and tissue for short term and long-term implantations.
Course Description	The course covers the principles of materials science and engineering with particular attention to topics most relevant to biomaterials. This course will cover the structure-property relationships of metals, ceramics, polymers, and composites with respect to their utility as biomaterials. This course will also give an overview of the different types of materials used in biomedical applications.
Course Content	Introduction: Definition and scope of biomaterials, Classification of bio-ceramic materials. Alumina and zirconia in surgical implants and their coatings. Bioactive glasses and glass ceramics with their clinical applications. Synthesis and characteristics of dense and porous hydroxyapatite and calcium phosphate ceramics. Resorbable bioceramics. Characterization of bio-ceramics. Structure-property relationship of biological materials: structure of proteins, polysaccharides, structure-property relationship of hard tissues cell, bone, teeth and connective tissues. Structure, properties and functional behaviour of bio-materials. Tissues response to implants (biocompatibility, wound healing process), body response to implants, blood compatibility. Application: Classification of bioceramic materials for medical applications, Carbon as an implant. Regulation of medical devices, Cell culture of bio ceramics, network connectivity and hemolysis, Preparation of bio ceramics and characterization of bioactivity. Bio-polymers: Polysaccharide based polymers, gelatinization, starch based blends, biodegradation of starch based polymers, production of lactic acid and polylactide, properties and applications of polylactides, introduction to polyhydroxyalkanoates and their derivatives, applications, chitin & chitosan and its derivatives as biopolymers, biopolymer films, biodegradable mulching, advantages and disadvantages, chemical sensors, biosensors, functionalized biopolymer coatings and films. Applications of biopolymers: Food Packaging, functional properties, safety and environmental aspects, shelf life, films and coatings in food applications, applications of biopolymers for organ transplant, different biopolymers used for organ transplant e.g. dental cement,

	orthopedic, skin, artificial kidney etc., applications of biopolymers in tissue engineering, regeneration, Targeted drug delivery: Introduction to drug delivery, polymers in controlled and targeted drug delivery, dressing strips, polymer drug vessels, core shell and nanogels. Application based and material based classification of biomaterials. Drug delivery, Callipers, biosensors, implants.
Learning Outcome	Upon completion of this course, the student will be able to: Understand the multidisciplinary nature of biomaterials as a field of study and define design criteria for a material with relationship to their clinical application Understand how to analyse the interaction of materials with the human body and what biocompatibility is in relation to specific materials Analyse issues relevant to property retention for materials when implanted in the human body and be capable of reading, comprehending and communicating the content of technical articles on biomaterials research and applications.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. An Introduction to Bioceramics: Larry L. Hench, June Wilson, World Scientific, 1993.
2. Biomaterials: An Introduction: Park Joon, R. S. Lakes, Springer, 2007.
3. Biopolymers-New Materials for Sustainable films and Coatings: David Plackett, John Wiley & Sons Ltd., 2011
4. Biopolymers from Renewable resources: David Kaplan, Springer, 1998

Reference Books:

1. Bioceramics and their Clinical Applications: T. Kokubo, Woodhead Publishing, 2008.
2. Biopolymers: R. M. Johnson, L. Y. Mwaikambo, N. Tucker, Rapra Technology, 2003.
3. Hand Book of Bioplastics & Biocomposites for Engineering Applications: Srikanth Pillai, Wiley, 2011.
4. Biopolymers: Steinbuechel Alexander, Vol. 1-10, Wiley, 2003.
5. Polymers from Renewable Resources: Biopolymers and Biocatalysis: Carmen Scholz, Richard A. Gross American Chemical Society, 2001.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Sl. No.	Subject Code	Departmental Elective - V	L	T	P	C
1.	MM4205	Crystallographic Texture and Analysis	3	0	0	3
2.	MM4206	Furnace and Refractories	3	0	0	3
3.	MM4207	Composite Science and Technology	3	0	0	3

Course Number	MM4205
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Crystallographic Texture and Analysis
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the concept of crystallographic texture and its importance in material properties To gain knowledge of various techniques used to characterize crystallographic texture in polycrystalline materials. To learn the interpretation of texture data and relate it to the microstructure and deformation behaviour of materials.
Course Description	A specialized course exploring the principles and techniques used to characterize and analyze the preferred orientation of crystals within a polycrystalline material, essential for understanding material anisotropy and behavior.
Course Content	Concept of texture: Crystal orientation, sample coordinate system, crystal coordinate system, stereographic projections, pole figure, construction of pole figures, reading pole figures and inverse pole figures. Orientation distribution functions, Bunge convention, Euler angles, Euler space, two-dimensional representation of ODF, and identification of standard texture components in Euler space. Texture measurement: Bulk and local texture measurements, electron diffraction using SEM and TEM, Kikuchi lines and indexing, Hough transformation, orientation imaging microscopy, X-ray and neutron diffraction measurement. Transmission EBSD. Texture during material processing: Deformation, annealing and recrystallization texture. Solidification and transformation texture. Texture in thin films and coatings. Influence of texture on mechanical properties. Case studies: Texture control in electrical steel, aluminium alloys, shape memory alloys, magnetic materials.
Learning Outcome	Upon completion of this course, the student will be able to: Explain the connection between crystallographic texture, microstructure, and mechanical properties of materials. Analyse and interpret texture data using relevant software or tools Apply the understanding of texture to predict and improve material performance in various engineering applications.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Introduction to Texture Analysis: Macrotexture, Microtexture and orientation mapping: V. Randle and O. Engler, 2nd Ed., CRC Press, 2009.

2. Recrystallization and Related Annealing Phenomenon: F.J. Humphreys, M. Hatherly, 2nd Ed., Pergamon Press, 2004.

Reference Books:

1. An Introduction to Textures in Metals: M. Hatherly and W.B. Hutchinson, The Institute of Metals, 1979.
2. DST-SERC School Lectures on Texture.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM4206
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Furnace and Refractories
Learning Mode	Lecture
Prerequisite	
Learning Objectives	To be able to explain the composition, classification and properties of refractories. To be able to evaluate mechanical properties, thermal behaviour and slag resistance of refractory materials. To be able to evaluate the design, performance, and lifetime of refractories for industrial applications.
Course Description	This course provides general overview on the importance of furnaces for melting metals, ceramics and glasses by providing the details of the types of refractories used in them along with their fundamental properties and characterizations.
Course Content	Furnaces: Fundamentals of furnace design, thermodynamics of fuel combustion, chemical reaction and enthalpy evolution, importance of heat balance, Sankey and virtue diagrams, temperature of flame, electric furnaces, advance furnaces, different heat loss in furnaces, choice of insulation, waste heat management through recuperation and regeneration, fuel economy and thermal efficiency of furnaces, principles of temperature and atmosphere control Various types of furnaces utilized in metallurgy/ ceramic industries, blast furnaces, open-hearth furnaces, Bessemer converters, LD converters, coke-oven batteries, tunnel kilns, chamber furnaces, glass tank furnaces, rotary kilns. Refractories: Composition, physical and chemical properties of raw materials; Principles of manufacturing of firebricks, silica, alumina, mullite, magnesite, chrome-magnesite, dolomite, magnesia, forsterite and insulating bricks along with relevant phase diagrams, spinel, borides, carbides, nitride, and carbon refractories Application of refractories in a blast furnace, open hearth furnace, Bessemer and L.D. converter, copper, aluminum, cement, lime, and glass industry. monolithic refractories, use of monolithic over shaped refractories. Testing of refractories: Bulk density, porosity, fusion point, cold crushing strength, creep resistance, pyrometric cone equivalent and refractories under load, hot modulus of rupture, abrasion resistance, thermal conductivity, thermal expansion and spalling, corrosion, and reaction of refractories.
Learning Outcome	Upon completion of this course, the student will be able to: Demonstrate a clear understanding of the types of refractories used for different industries Interpret the information on chemical and mineral compositions, thermal conductivity, and micro-structural examinations and other characterization carried out on refractory bricks.

	Evaluate the industrial application of various refractory materials, their design, performance and testing methods.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Industrial ceramics: Felix Singer, Sonja S. Singer, Chapman & Hall, Springer, 1963.
2. Refractories: F.H. Norton, CbIs\Ceramic book and Literature, 1985.
3. Industrial and Process Furnaces: P. Mullinger and B. Jenkins, Butterworth Heinemann, Elsevier, 2013.

Reference Books:

1. Fundamentals of Materials for Energy and Environmental Sustainability: G. David and C. David, Cambridge University Press, 2011.
2. The Technology of Ceramics and Refractories: Petr Petrovich Budnikov, M.I.T. Press, 1964.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM4207
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Composite Science and Technology
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To disseminate details regarding the various kinds of composites, their requirements, and their benefits. To disseminate knowledge on how various composites are prepared. To provide knowledge on the characteristics, uses, and testing of various composites.
Course Description	The course covers the basic and important knowledge of various composites fabricated from metals, ceramics and polymers. This course will also cover essential details about the types of composite materials, various components of composites, common manufacturing/processing techniques, testing and characterization of composites and how to select composite materials for particular applications.
Course Content	Metal matrix composites (MMCs): Overview, significant of metallic matrices, Characteristics and uses of MMCs. Processing of metal matrix composites: liquid state processing: melt stirring, compocasting (rheocasting), squeeze casting, liquid infiltration under gas pressure; solid state processing: diffusion bonding, powder metallurgy; Deposition: in-situ processes, spray co-deposition, and other deposition methods including CVD and PVD. Interface reactions. Ceramic matrix composites (CMCs): Introduction; processing and structure of monolithic materials – technical ceramics, glass-ceramics. Processing of ceramics: conventional mixing and pressing – cold pressing and sintering, hot pressing; Reaction bonding processes, techniques involving slurries, liquid state processing – matrix transfer moulding, liquid infiltration, sol-gel processing; Carbon-carbon composites - porous carbon-carbon composites, dense carbon-carbon composites. Properties and applications of CMCs; Glass-ceramic matrix composites; Processing, properties and applications of alumina matrix composites - SiC whisker reinforced, zirconia toughened alumina; Vapour deposition techniques like CVD, CVI, liquid phase sintering, Lanxide process and in situ processes. Polymer matrix composites (PMCs): Thermoset matrices–polyesters, epoxides, phenolics, vinyl esters, polyimides and cyanate esters, thermoplastic matrices and rubber matrices. Fibers: Glass, carbon, kevlar, natural fibers and surface treatment- sizing/coupling agents. Interfaces: Wettability, the type of bonding at the interface, its crystallographic character, and the ideal interfacial bond strength. Processing: Sheet molding compounds, bulk molding compounds, hand layup process, spray layup process, resin transfer molding, pressure bag molding, vacuum bag molding, autoclave molding, filament winding and pultrusion. Properties and applications of PMCs. Testing of composites: Destructive and non-destructive testing of composites

	Analysis of composites: Micro-mechanics, macro-mechanics and failure theories.
Learning Outcome	Upon completion of this course, the students will be Able to choose appropriate composites for specific applications. Able to comprehend about the many techniques used in the manufacturing of composite materials Able to select suitable testing procedures for composite analysis.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Chawla. K.K., Composite Materials - Science and Engineering, Springer, 2001.
2. Jones, R.M., Mechanics of Composite Materials, Taylor and Francis, 1999.
3. P. K. Mallick, Composites Engineering Handbook Part-1&2, CRC Press (2016).

Reference Books:

1. Lubin, G., Handbook of Composites, Van Nostrand Reinhold Co., 1982.
2. Eckold, G., Design and Manufacture of Composite Structures, Wood head Publishing Ltd., 1994.
3. F. R. Jones (Ed.), Handbook of Polymer-Fibre Composites, Longman Group (1994).
4. K. Friedrich, S. Fakirov, Z. Zhang (Eds.), Polymer Composites – from Nano to Macro scale, Springer (2005).

	CLO1	CLO2
PLO1	X	
PLO2		X
PLO3	X	

Sl. No.	Subject Code	Interdisciplinary Elective (IDE)	L	T	P	C
1.	MM2206	Structure and Properties of Materials	3	0	0	3
2.	MM3106	Microscopy and X-ray Diffraction	3	0	0	3
3.	MM4107	Nanomaterials	3	0	0	3

Course Number	MM2206
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Structure and Properties of Materials (IDE I)
Learning Mode	Lecture
Prerequisite	
Learning Objectives	To provide an introductory level understanding of material structure (microstructure) on different length scales. To understand how specific material properties and behaviours are determined by the associated structure.
Course Description	Basic course to differentiate various solids (like metal, ceramics and polymer) from the aspects of crystal structure, properties and applications.
Course Content	Bonding in solids: primary and secondary bonding in solids, bond strength and bond energy. Basic crystallography: crystalline and amorphous materials. Packing of atoms, coordination number, unit cell, Bravais lattice, simple crystal structures, defects in solids, Miller indices Classification of materials: engineering materials and their classification, metallic materials, ceramic materials and polymeric materials. Composite materials. Properties of materials: mechanical, electrical, magnetic and optical properties. Microstructure-property correlation in materials. Materials selection: introduction to materials selection charts, Ashby maps, materials performance index, processability and cost.
Learning Outcome	On completion of the course the students will be able to Differentiate between different types of materials and their structures Understand the structure dependence of properties and design materials for various engineering applications
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Materials Science and Engineering, an Introduction: William D. Callister, 7th Ed., John Wiley and Sons, 2007
2. Materials Science and Engineering: V. Raghavan, 6th Ed., Prentice Hall India, 2015.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM3106
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Microscopy and X-ray Diffraction (IDE II)
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the availability of various techniques to characterize materials. To understand the strengths and limitations of different characterization techniques.
Course Description	The course deals with the structural analysis of material at different length scales, such as micro, nano and angstrom levels, using different techniques
Course Content	Introduction: Importance and the need for materials characterization, bonding, crystal structure and system, miller indices, Bravais lattice. Diffraction: Basics of diffraction and interference of light, Young's double slit experiment, interpretation of diffraction from the single slit and multiple slits. X-ray Diffraction: Generation of X-rays, X-ray diffraction (XRD), Bragg's Law, Atomic scattering factor, structure factor, indexing of diffraction patterns, selection rules, estimation of peak intensity, phase identification and analysis by XRD, determination of structure and lattice parameters, strain and crystallite size measurements through XRD, effect of temperature on XRD. Optical Microscopy: Principles of optical microscopy, magnification, Rayleigh criterion, resolution limitation, Airy disk, depth of focus, and field. Electron diffraction: Wave properties of the electron, electron-matter interactions, ring patterns, spot patterns, and Laue zones. Scanning Electron Microscopy: Principle, construction, and operation of Scanning Electron Microscope, SE and BSE imaging modes, Elemental analysis using Energy dispersive analysis of X-rays, Transmission electron microscope: Principle, construction, and working of Transmission Electron Microscope (TEM), the origin of contrast: mass-thickness contrast, electron diffraction pattern, Bright field, and dark field images. Thermal characterization techniques (DTA, DSC, DTA)
Learning Outcome	Upon completion of this course, the student will be able to: Understand structure and microstructure of materials Choose the appropriate technique to characterise different materials
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Elements of X-Ray Diffraction: B.D. Cullity and S.R. Stock, 3rd Ed., Pearson, 2001.
2. Scanning Electron Microscopy and X-Ray Microanalysis: Joseph Goldstein, Eric Lifshin, Charles E. Lyman, David C. Joy and Patrick Echlin, 3rd Ed., Springer, 2003.

Reference Books:

1. Transmission Electron Microscopy: A Textbook for Materials Science: David B. Williams and C. Barry Carter, Springer, 2009.
2. Structure of Materials: An Introduction to Crystallography, Diffraction and Symmetry, Marc De Graef, Michael E. McHenry; 2nd Ed., Cambridge University Press, 2012.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM4107
Course Credit (L-T-P-C)	(3-0-0) (3 AIU Credits)
Course Title	Nanomaterials (IDE III)
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the influence of dimensionality at nanoscale on their properties To understand the size and shape-controlled synthesis of nanomaterials and their current and futuristic applications/challenges. To visualize the applications of nanomaterials in their routine life
Course Description	The course serves to provide students with a comprehensive understanding of the nanomaterials ecosystem, including its synthesis, fundamentals, properties, and applications.
Course Content	Overview: Overview of Nanostructures and Nanomaterials; Characteristic length scales of materials. Classification-Natural nanomaterials, artificial nanomaterials, Inorganic nano materials-Metal-based nanoparticles, Metal oxide nanoparticles, Semiconductor Nanoparticles, Ceramic nanomaterial, Composites nanomaterials. 3D, 2D, 1D and 0 Dimensional Nanomaterials. Carbon Nanotubes, Fullerenes, Nanowires, Quantum Dots. Applications of nanostructures, Surfaces and interfaces in nanostructures, Grain boundaries in Nanocrystalline materials, Defects associated with nanomaterials, Micro porous, Mesoporous materials and Macro porous materials. Fundamentals: Various electron confinements in nanomaterials, concept of quantum well, dots and wires and thermodynamics of nanomaterials Nanomaterials' manufacturing: Top down approaches: mechanical milling, electrospinning; Lithography, sputtering, the arc discharge method; laser ablation, thermal decompositions. Bottom-up approaches: chemical vapour deposition (CVD), solvothermal and hydrothermal growth; sol-gel method and electrochemical and pyrolysis approaches. Properties of Nanostructures and Nanomaterials: Surface area, thermal and electrical conductivity, mechanical properties; support for catalysts, Optical and electrical properties, physical and chemical properties of nanomaterials.
Learning Outcome	Upon completion of this course, the student will be able to: Appreciate the quantum effects operating at nanoscale on the properties of materials. Design, synthesize and characterize materials at nanoscale. Contrast the properties of materials at the nanoscale relative to its bulk counterpart and apply nanomaterials for advanced industrial applications.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Booker, R., Boysen, E., Nanotechnology, Wiley India Pvt. Ltd. (2008).

2. Rogers, B., Pennathur, S., Adams, J., Nanotechnology, CRS Press (2007).
3. Bandyopadhyay, A.K., Nano Materials, New Age Int., (2007)

Reference Books:

1. Dr. Kurt E. Geckeler, Prof. Hiroyuki Nishide, Advanced Nanomaterials: Copyright © 2010 Wiley-VCH Verlag GmbH & Co. KGaA
2. Jingbo Louise Liu, Sajid Bashir Tian-Hao Yan, Advanced Nanomaterials and Their Applications in Renewable Energy.
3. Nanomaterials, Nanotechnologies and Design: An Introduction to Engineers and Architects, D. Michael Ashby, Paulo Ferreira, Daniel L. Schodek, Butterworth-Heinemann, 2009.
4. S. Cambell, The Science & Engineering of Microelectronic Fabrication, Oxford, 1996.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	