

NATIONAL INSTITUTE OF TECHNOLOGY ANDHRA PRADESH



COURSE STRUCTURE

Department of Metallurgical and Materials Engineering

M.Tech. (Materials Technology)

Effective from 2025-26

I – Year: I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	25MM601	Advanced Metallurgical Thermodynamics & Kinetics	3	0	0	3	PCC (T)
2	25MM602	Advanced Mechanical Testing of Materials	3	0	0	3	PCC (T)
3	25MM603	Advances in Materials Characterization	3	0	0	3	PCC (T)
4		Department Elective – I	2	0	0	2	DEC (T)
5		Department Elective – II	2	0	0	2	DEC (T)
6		Open Elective – I	2	0	0	2	OEC (T)
7	25MM610	Materials Testing and Characterization Laboratory	0	0	3	2	PCC (P)
Total						17	

I – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	25MM604	Synthesis & Applications of Nanomaterials	3	0	0	3	PCC (T)
2	25MM605	Advanced Composite Materials	3	0	0	3	PCC (T)
3	25MM606	Materials for Energy Systems	3	0	0	3	PCC (T)
4		Department Elective – III	2	0	0	2	DEC (T)
5		Department Elective - IV	2	0	0	2	DEC (T)
6		Research Methodology and Strategies in English	2	0	0	2	HEC (T/P)
7	25MM697	Orientation towards Industrial Practices & Seminar	0	0	3	2	PCC (P)
Total						17	

II – Year: I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	25MM698	Dissertation Part A	13	0	0	13	Diss.
Total						13	

II – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	25MM699	Dissertation Part B	13	0	0	13	Diss.
Total						13	

List of Elective Courses:

Year & Semester	Course Code	Course Title
Department Elective I		
I - Year I - Semester	25MM621	Environmental Degradation of Materials
	25MM622	Metallurgical Failure Analysis & Prevention
	25MM623	Welding Science and Technology
Department Elective II		
I - Year I - Semester	25MM624	High Temperature Materials
	25MM625	Biomaterials
	25MM626	Smart Materials
Department Elective III		
I - Year II - Semester	25MM627	Powder Metallurgy and Technology
	25MM628	Principles & Applications of Additive Manufacturing
	25MM629	Non-Destructive Testing
Department Elective IV		
I - Year II - Semester	25MM630	Phase Diagrams for Materials Engineers
	25MM631	Symmetry & Crystallography
	25MM632	Integrated Computational Materials Engineering

Credit Requirements

Category	Category Description	Credits
PCC (T)	Programme Core Course (Theory)	18
PCC (P)	Programme Core Course (Practical)/ Seminar/ Dissertation	4
DEC (T)	Department Elective Course (Theory)	8
OEC (T)	Open Elective Course (Theory)	2
HEC (T/P)	Humanities Elective Course (Theory/Practical)	2
Diss.	Dissertation	26
Total		60

DETAILED SYLLABUS

I – Year: I – Semester

	Advanced Metallurgical Thermodynamics & Kinetics	PCC(T)	3-0-0	3 Credits
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Pre-requisites: None

Syllabus:

Module-1: Thermodynamic definitions and basic concepts; laws of thermodynamics and their metallurgical applications; equation of state; reversible and irreversible processes; Maxwell's relations; Gibbs-Helmholtz equation; introduction to statistical thermodynamics..

Module-2: Phase equilibria in unary and multicomponent systems; variation of Gibbs free energy with pressure and temperature; phase rule, ideal and non-ideal solutions; activity, chemical potential, and common solution models; thermodynamics of gases and non-ideal systems.

Module-3: Thermodynamics of phase transformations and reactions; nucleation theory; Clausius-Clapeyron equation; oxidation, reduction, and electrochemical equilibria; construction and interpretation of Pourbaix and Ellingham diagrams; free energy–composition diagrams.

Module-4: Kinetics of metallurgical processes – diffusion, nucleation and growth; Johnson-Mehl-Avrami-Kolmogorov theory; TTT and CCT diagrams; Interface-controlled and diffusion-controlled transformations; Reaction rate theory and transition state theory; Application of thermodynamic and kinetic principles in the design of advanced alloys (e.g., CALPHAD-based alloy design approach). Exposure to case studies and expert talks from the alloy development, aerospace, and thermal systems industries.

Text Books:

1. D.R. Gaskell: Introduction to the Thermodynamics of Materials, 5th Ed, CRC Press, 2008.
2. A. Ghosh: Text Book of Materials and Metallurgical Thermodynamics, Prentice Hall, 2003.

Reference Books:

3. M.L. Kapoor: Chemical and Metallurgical Thermodynamics, Vols 1-2, Nemchand & Bros, 1984.
4. G. S. Upadhyaya, R. K Dube: Problems in Metallurgical Thermodynamics and Kinetics, Pergamon, 1982.
5. S.K. Dutta, A.B. Lele: Metallurgical Thermodynamics Kinetics and Numericals, 2012.

	Advanced Mechanical Testing of Materials	PCC(T)	3-0-0	3 Credits
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Pre-requisites: None

Syllabus:

Module-1: Review of crystal structures, elastic anisotropy, and theoretical strength of solids; stress-strain behavior in tension, compression, and torsion; Bauschinger effect; true stress-strain analysis; application of yield and failure criteria (von Mises, Tresca, Mohr-Coulomb) in metal forming and structural design; Case studies on forming load estimation in rolling and forging processes.

Module-2: Dislocation types, motion, and interactions; influence of temperature and strain rate; strengthening mechanisms – solid solution, grain refinement, precipitation, and work hardening; fracture mechanics – crack initiation and propagation, K_{IC} , J-integral, and crack tip opening displacement (CTOD); Case studies on damage tolerance estimation in aerospace alloys.

Module-3: Fatigue and creep testing under service conditions; S-N and ϵ -N curves, fatigue crack growth, mean stress effects, and fatigue regimes; creep mechanisms – diffusional, dislocation, superplasticity; multiaxial and thermo-mechanical creep; creep-fatigue interaction; stress vs. creep rupture; life extrapolation (Larson-Miller, Monkman-Grant) and design curve generation.

Module-4: Advanced techniques – nanoindentation; thermo-mechanical simulation of forming and service exposure; prediction of processing parameters using flow curves and workability maps. Mechanical testing of non-metallic materials – polymers (tensile, DMA), ceramics (flexural, indentation), and composites (interlaminar shear, fatigue crack growth); comparison of failure modes across material classes. Includes industry-relevant case studies and expert talks from aerospace, automotive, and energy sectors.

Text Books:

1. G.E. Dieter: Mechanical Metallurgy, McGraw-Hill, 2002.
2. M.A. Meyers, K. Chawla: Mechanical Behavior of Materials, 2nd Edition, Cambridge University Press, 2009.

Reference Books:

3. R.W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, 4th Ed., John Wiley & Sons, 1995.
4. T.L. Anderson: Fracture Mechanics – Fundamentals and Applications, 3rd Ed., CRC Press, 2011.
5. F.C. Campbell: Manufacturing Technology for Aerospace Structural Materials, Elsevier, 2006.

	Advances in Materials Characterization	PCC(T)	3-0-0	3 Credits
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Pre-requisites: None

Syllabus:

Module-1: Optical Microscopy – principles, contrast mechanisms, and limitations; Scanning Electron Microscopy (SEM) – secondary/backscattered electron imaging and detectors; Electron Probe Micro Analysis (EPMA); Energy and Wavelength Dispersive Spectroscopy (EDS, WDS) – resolution and elemental analysis; Scanning Probe and Atomic Force Microscopy (SPM, AFM) – imaging modes; Transmission Electron Microscopy (TEM) – bright/dark-field imaging, SAD patterns, and sample preparation.

Module-2: X-ray Diffraction (XRD) – Bragg’s law, diffraction geometries, interpretation of patterns for metals, ceramics, and composites; lattice parameter and crystallite size estimation; instrumental broadening, peak shift, and Rietveld refinement; diffraction from ordered structures and superlattices. Includes live/virtual demonstration at research facility.

Module-3: Spectroscopic techniques in materials characterization – Fourier Transform Infrared Spectroscopy (FTIR), Raman Spectroscopy, UV-Vis Spectroscopy – principles and materials applications; limitations and interpretation strategies. Introduction to surface and interface chemical analysis – X-ray Photoelectron Spectroscopy (XPS), Auger Electron Spectroscopy (AES), and Secondary Ion Mass Spectrometry (SIMS).

Module-4: Thermal and advanced analytical methods – Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA), Dilatometry, and Dynamic Mechanical Analysis (DMA); tomography and 3D reconstruction techniques; Convergent Beam Electron Diffraction (CBED); advanced TEM modes for thin films and multilayers; Atom Probe Tomography (APT) – principles, specimen preparation, and spatial resolution. Includes hands-on exposure or virtual training at IIT Hyderabad characterization facilities.

Text Books:

1. Yang Leng: Materials Characterization- Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia), 2008.
2. David Brandon and Wayne D. Kaplan, Microstructural Characterization of Materials, 2nd Ed., Wiley, 2008.

Reference Books:

3. ASM Metals Handbook, Vol 3: Materials Characterization, ASM International, 2008.
4. V.T. Cherapin and A.K. Mallik, Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.
5. Robert F. Speyer, Thermal Analysis of Materials, Marcel Dekker, 1994.

Department Elective I

	Environmental Degradation of Materials	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Importance and classification of corrosion; Electrochemical mechanism of corrosion; Dry-cell analogy and Faraday's laws; Types of electrochemical cells; Environmental and metallurgical factors; Forms of corrosion damage – uniform, pitting, crevice, intergranular; Stress corrosion cracking (SCC) – mechanism, microstructural evaluation, influencing factors.

Module-2: Corrosion prevention techniques – design considerations, material selection; Stray current corrosion and mitigation; Cathodic protection (sacrificial anode and impressed current systems); Protective coatings – metallic, inorganic and organic; Corrosion inhibitors and passivators – types, mechanisms, applications.

Module-3: Corrosion rate measurement – weight loss, polarization resistance, Tafel extrapolation; Electrochemical Impedance Spectroscopy (EIS); Oxidation – kinetics and parabolic rate law; Thermodynamics of oxidation; Ellingham diagrams and oxidation behavior of metals and alloys.

Module-4: Hot corrosion – Type I and Type II; Protective vs non-protective oxide scales; Role of alloying and reactive element effect (REE); Corrosion by sulfates and chlorides at elevated temperatures; High-temperature corrosion in gas turbines and boilers; Failure analysis of corroded components and case studies.

Text Books:

1. Mars Guy Fontana: Corrosion Engineering, 3rd Ed., Tata McGraw-Hill Education, 2005.
2. H.H. Uhlig, R. Winston Revie: Corrosion and Corrosion Control, 4th Ed., John Wiley & Sons, 2008.

Reference Books:

3. P.R. Roberge: Corrosion Engineering – Principles and Practice, McGraw-Hill, 2008.
4. Zaki Ahmad: Principles of Corrosion Engineering and Corrosion Control, Elsevier, 2006.
5. Joseph R. Davis (Ed.): Corrosion: Understanding the Basics, ASM International, 2000.

	Metallurgical Failure Analysis & Prevention	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Objectives and importance of failure analysis; common causes of premature failures in metals and alloys; systematic failure investigation methodology; tools and techniques – visual inspection, fractography, sample preservation; use of optical microscopy, SEM/TEM, and non-destructive testing (NDT) in failure diagnosis.

Module-2: Types and mechanisms of failure – ductile, brittle, fatigue, creep, corrosion, and wear; fracture surface morphology and interpretation; embrittlement mechanisms – hydrogen, temper, and liquid metal embrittlement; role of microstructure and phase transformations in influencing failure behavior; environmental effects.

Module-3: Process-induced failures – heat treatment-related (quenching cracks, retained austenite, decarburization), welding and joining defects, residual stress effects, casting defects, and forming failures; design-related failures – stress concentration, geometry, and material selection; standards and protocols (ASTM, ISO) for root cause analysis.

Module-4: Failure prevention strategies – design modifications, controlled heat treatments, and alloying; prevention of creep, fatigue, brittle-to-ductile transition (BTT), and stress corrosion cracking (SCC); examples from power plants, pipelines, and marine industries (e.g., ship hull cracking); strategies in green steelmaking for sustainability and performance; industrial case studies with root cause–solution mapping from sectors like automotive, aerospace, and energy.

Text Books:

1. A. K. Das: Metallurgical Failure Analysis, McGraw Hill, 1997.
2. Charles R. Brooks, Ashok Choudhury: Failure Analysis of Engineering Materials, McGraw-Hill, 2002.

Reference Books:

3. ASM Handbook, Vol. 11: Failure Analysis and Prevention, ASM International, 2002.
4. D. Broek: Elementary Engineering Fracture Mechanics, 3rd Rev. Ed., Springer, 1982.
5. S. Suresh: Fatigue of Materials, 2nd Ed., Cambridge University Press, 1998.

	Welding Science and Technology	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Overview of welding processes – arc, resistance, beam (Electron Beam Welding, Laser Beam Welding), solid-state (Friction Welding, Friction Stir Welding), and emerging processes (Cold Metal Transfer, Hybrid Welding); fundamentals of heat flow, thermal cycles, weld pool dynamics, fluid flow, and vaporization; role of shielding gases and modes of metal transfer; practical demonstrations of selected welding processes and power sources.

Module-2: Solidification in welds – columnar/equiaxed growth, segregation phenomena; microstructural evolution in weld metal and Heat Affected Zone (HAZ); formation of weld inhomogeneities and precipitates; grain coarsening and transformations in HAZ; residual stress generation, distortion, and fatigue performance of welded joints. Application case: Pressure vessel and pipeline welds.

Module-3: Weldability and defects – hot cracking, liquation and cold cracking, hydrogen-induced cracking, partially melted zone (PMZ) behavior, lamellar tearing and reheat cracking; cracking susceptibility tests; non-destructive inspection (UT, RT, PT, MT) and standards for weld quality (AWS, ASME); failure case studies in critical service environments (marine, energy, structural).

Module-4: Post-weld heat treatments (PWHT) and weld repair techniques; welding of dissimilar and hard-to-weld alloys (stainless steels, titanium, Ni-alloys, aluminium-lithium); welding design principles – joint types, residual stress mitigation, and electrode/filler selection; introduction to automation and digital welding systems; Industry-focused module with job-oriented skills, expert talks, and examples from shipbuilding, aerospace, and energy sectors.

Text Books:

1. R.S. Parmer: Welding Processes and Technology, Khanna Publishers, 2006.
2. L.M. Gourd: Principles of Welding Technology, 2nd Ed., ELBS Longman, 2008.

Reference Books:

3. Sindo Kou: Welding Metallurgy, Wiley-Interscience, 2nd Ed., 2003.
4. John Norris: Advanced Welding Processes, Woodhead Publishing, 2006.
5. ASM Handbook, Vol. 6: Welding, Brazing, and Soldering, ASM International, 1993.

Department Elective II

	High Temperature Materials	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Materials challenges and degradation mechanisms at elevated temperatures – oxidation, creep, thermal fatigue, and hot corrosion; Design criteria for high-temperature service in aerospace, automotive, and turbine components; Industrial and practical applications of high-temperature materials in gas turbines, jet engines, heat exchangers, and nuclear systems; Influence of service temperature and mechanical loading on material selection.

Module-2: Superalloys – classification (Ni-, Co-, Fe-based), microstructure, and strengthening mechanisms (solid solution, precipitation, dispersion); Role of alloying additions including refractory metals (Mo, W, Ta, Re) in enhancing creep strength and phase stability; Processing techniques – Vacuum Induction Melting (VIM), Vacuum Arc Remelting (VAR), and Electro Slag Remelting (ESR); Heat treatment practices and microstructure-property relationships; Creep and fatigue behavior under thermal exposure.

Module-3: Stainless steels – types (ferritic, martensitic, austenitic, duplex), alloying effects, and high-temperature corrosion resistance; Phase stability, carbide precipitation, sensitization, and sigma-phase formation; Selection strategies for structural and elevated-temperature environments including boilers and reformers.

Module-4: Ferritic-martensitic steels for advanced fossil and nuclear power plant components; Creep rupture performance, oxidation resistance, and weldability; Zirconium alloys for nuclear fuel cladding – corrosion resistance, hydrogen pickup, and irradiation-induced effects; Radiation damage mechanisms, swelling, embrittlement, and design for structural integrity at high temperatures.

Text Books:

1. G. W. Meetham and M. H. Van de Voorde, Materials for High Temperature Engineering Applications, Springer, 2000.
2. R. W. Chan, High Temperature Structural Materials, Chapman & Hall, 2000.

Reference Books:

3. S. Somiya, Handbook of Advanced Ceramics, Academic Press, 2006 (Parts 1 & 2).
4. C.T. Sims, N.S. Stoloff, W.C. Hagel, Superalloys II: High-Temperature Materials for Aerospace and Industrial Power, Wiley, 1987.
5. F.R.N. Nabarro and H.L. de Villiers, The Physics of Creep, Taylor & Francis, 1995.

	Biomaterials	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Introduction to biomaterials and their classification; Requirements for biomedical applications – biocompatibility, sterility, mechanical compatibility, and corrosion resistance; Stainless steels and Co-Cr alloys – composition, passive films, degradation behavior; Applications in orthopedic, cardiovascular, and dental implants; Case examples in load-bearing prosthetics and joint replacements..

Module-2: Titanium and its alloys – mechanical and biological properties, surface passivation, and modifications for enhanced osseointegration; Medical-grade polymers – classification, degradation mechanisms (hydrolytic, enzymatic), structure-property relations; Bioresorbable and bioerodible polymers for sutures, stents, and scaffolds; Industrial examples and processing challenges.

Module-3: Ceramic biomaterials – bioinert (Al₂O₃, ZrO₂) vs bioactive ceramics (hydroxyapatite, tricalcium phosphate, bioglass); Fabrication of porous ceramics for bone regeneration; Dental ceramics and coating technologies; Industrial processing of calcium phosphate materials for synthetic bone grafts and dental prosthetics.

Module-4: Natural and hybrid biomaterials – collagen, gelatin, alginate, hydrogels, protein-based systems; Elastomers and latex in catheters, valves, and contact lenses; Thin film coatings and surface engineering for implants; Functional biomaterials in drug delivery, tissue scaffolds, and regenerative engineering; Translational challenges – sterilization, shelf life, manufacturing validation, and regulatory approvals (FDA/ISO).

Text Books:

1. Buddy D. Ratner et al., Biomaterials Science: An Introduction to Materials in Medicine, Elsevier, 2004.
2. D.F. Williams, Essentials of Biomaterials, Cambridge University Press, 2014.

Reference Books:

3. D. Shi, Biomaterials and Tissue Engineering, Springer, 2004..
4. S.V. Bhatt, Biomaterials, Narosa Publishing House, 2002.
5. Jeffrey O. Hollinger (Ed.), An Introduction to Biomaterials, CRC Press, 2011.

	Smart Materials	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Definition and classification of smart materials; Distinction from conventional materials; Composites with integrated functionalities; Piezoelectric, magnetostrictive, and ferroelectric materials; Thermo-responsive and photoresponsive materials; Application examples in aerospace skins, sensors, and actuators.

Module-2: Shape Memory Alloys (SMAs) – crystallographic mechanisms, stress-strain-temperature behavior, hysteresis, and fatigue; Electro-Rheological (ER) and Magneto-Rheological (MR) fluids – behavior, field-responsive properties, and device design; Functional optical fibers and electrochromic materials; Development and integration of smart materials in sensing and actuation platforms.

Module-3: Sensing and actuation principles – direct and converse effects, coupled field interactions; Discrete vs. distributed sensors and actuators; Smart structures – embedded sensing, self-diagnostics, and real-time health monitoring; Emerging topics – smart skin technologies, morphing structures, and intelligent wearables.

Module-4: Modeling and analysis of smart materials and systems – analytical formulations, finite element modeling, multiphysics simulations; Design strategies for adaptive materials; Applications in vibration suppression, active damping, shape control, and precision robotics; Industrial use-cases in aerospace, civil infrastructure, and biomedical devices.

Text Books:

1. K. Vijay, K. Varadan, J. Vinoy, S. Gopalakrishnan, Smart Material Systems and MEMS: Design and Development Methodologies, Wiley, 2006.
2. M.V. Gandhi and B.S. Thompson, Smart Materials and Structures, Chapman & Hall, 1992.

Reference Books:

3. B. Culshaw, Smart Structures and Materials, Artech House, 2000.
4. P. Gauenzi, Smart Structures: Physical Behaviour, Mathematical Modelling and Applications, Wiley, 2009.
5. M. Addington and D.L. Schodek, Smart Materials and New Technologies, Architectural Press, 2005.

Open Elective I (MOOCS)

		OEC(T)	2-0-0	2 Credits
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Pre-requisites: None

	Materials Testing and Characterization Laboratory	PCC(P)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

1. To determine the hardness of steel, aluminum, or copper alloys using Vickers, Brinell, and Rockwell testing systems.
2. To determine the impact strength of steel, aluminum, or copper alloys using Charpy and Izod testing, followed by fractographic analysis of fractured specimens to correlate microstructure and fracture behavior.
3. To determine the tensile behavior of steel, aluminum, or copper alloys using a Universal Testing Machine.
4. To examine the microstructure of etched samples and identify phases, quantitative metallography using optical microscopy and image analysis to measure grain size, phase fraction, and morphology.
5. To perform phase identification, lattice parameter calculation, and residual stress analysis in multiphase alloys using X-ray diffraction.
6. To conduct EIS and potentiodynamic polarization studies of a given alloy in different electrolytes to evaluate corrosion resistance and passivation characteristics using an electrochemical workstation to understand localized corrosion behaviour.
7. To perform pitting corrosion studies on steels, aluminium or stainless steels weldments to determine critical pitting potential and localized corrosion susceptibility.
8. To perform dilatometry or DSC experiments to measure phase transformation temperatures in steels and aluminum alloys.

I – Year: II – Semester

	Synthesis & Applications of Nanomaterials	PCC(T)	3-0-0	3 Credits
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Pre-requisites: None

Syllabus:

Module-1: Introduction to nanomaterials and nanotechnology – importance, historical development, and industrial impact; Top-down and bottom-up approaches in nanostructure fabrication; Challenges in scalability, agglomeration, and reproducibility; Physical methods for ultrafine powder production – mechanical grinding, attrition, high-energy ball milling; Overview of nanoscale size effects on structure and properties.

Module-2: Wet chemical synthesis techniques – sol-gel processing, precipitation, and hydrothermal methods; Gas-phase synthesis routes – furnace-based evaporation-condensation, flame spray pyrolysis, ultrasonic spray pyrolysis, and laser ablation; Physical and Chemical Vapour Deposition (PVD, CVD, CVC); Cold plasma processing, VLS growth mechanism, and GPC (Gas Condensation Processing); Safety and environmental aspects of nanopowder synthesis.

Module-3: Synthesis of nanocomposites – motivation, processing routes (ex situ/in situ), sol-gel and self-assembly methods, biomimetic approaches; Thin films and multilayer nanocomposites; Processing of nanoparticles and binding mechanisms; Strategies for enhancing dispersion, surface functionalization, and compatibility in matrix systems.

Module-4: Stabilization and dispersion of nanoparticles – steric and electrostatic techniques; Introduction to carbon-based nanomaterials – carbon nanotubes (CNTs), fullerenes, and graphene; Nano-bio materials for drug delivery, scaffolds, and tissue engineering; Mechanical testing at nanoscale – nanoindentation and nanohardness; Application case studies in energy (batteries, supercapacitors), catalysis, and smart coatings.

Text Books:

1. B.S. Murty, P. Shankar, Baldev Raj, B.B. Rath, James Murday, Textbook of Nanoscience and Nanotechnology, Universities Press, 2012.
2. C. N. R. Rao, A. Müller, A. K. Cheetham, The Chemistry of Nanomaterials: Synthesis, Properties and Applications, Wiley-VCH, 2006.

Reference Books:

3. G. Cao and Y. Wang, Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, 2nd Edition, World Scientific, 2011.
4. Dieter Vollath, Nanomaterials: An Introduction to Synthesis, Properties and Applications, Wiley-VCH, 2013.
5. Bharat Bhushan, Springer Handbook of Nanotechnology, Springer, 2017.

	Advanced Composite Materials	PCC(T)	3-0-0	3 Credits
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Pre-requisites: None

Syllabus:

Module-1: Introduction to composite materials – definitions, classification (PMCs, MMCs, CMCs, hybrid systems); Reinforcement mechanisms – load transfer, crack bridging, and fiber pull-out; Matrix and reinforcement types; Fabrication techniques for polymer matrix composites – hand lay-up, resin transfer molding, filament winding, pultrusion; Overview of metal and ceramic matrix composite processing (stir casting, pressure infiltration, powder processing, hot pressing).

Module-2: Fibre reinforced plastics – types, production of glass, aramid, and carbon fibers; Mechanical properties and applications in aerospace, automotive, and infrastructure; Ceramic matrix composites and cermets – processing and wear resistance; Fatigue and failure mechanisms in composites; Introduction to sustainable materials – green composites, wood composites, and bio-based polymer nanocomposites; Processing and performance of environment-friendly composites.

Module-3: Mechanical testing of advanced composites – tensile, flexural, interlaminar shear, fatigue, impact, and creep behavior; Aging and degradation of composites under thermal and environmental conditions; Advances in high-temperature ceramic composites; Composite materials in aerospace, defense, and marine sectors; Design and performance of lightweight ballistic composites – processing challenges and impact response.

Module-4: Emerging composite architectures – porous composites and foam-core systems; Functionally Graded Materials (FGMs) – design principles, processing strategies, and property tailoring; Interface engineering in composites – chemical bonding, fiber-matrix compatibility, and interphase design; Thermal and environmental stability of advanced composites; Additive manufacturing of composites and ceramic systems; Industry-relevant case studies and applications in next-gen mobility, defense armor, wind energy, and biomedical implants.

Text Books:

1. K.K. Chawla, Composite Materials: Science and Engineering, Springer, 3rd Edition, 2012.
2. W.D. Kingery, H.K. Bowen, D.R. Uhlmann, Introduction to Ceramics, Wiley, 2nd Edition, 1976.

Reference Books:

3. Deborah D.L. Chung, Composite Materials: Science and Applications, Springer, 2nd Edition, 2010.
4. F.L. Matthews and R.D. Rawlings, Composite Materials: Engineering and Science, Woodhead Publishing, 1999.
5. I.M. Ward and J. Sweeney, Mechanical Properties of Solid Polymers, Wiley, 3rd Edition, 2012.

	Materials for Energy Systems	PCC(T)	3-0-0	3 Credits
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Pre-requisites: None

Syllabus:

Module-1: Introduction to energy systems and classification of energy sources – fossil, nuclear, renewable; Role of materials in energy generation, storage, and conversion; Materials performance criteria – mechanical, thermal, electrical, and corrosion resistance; Material degradation mechanisms in energy environments; Sustainability and lifecycle considerations.

Module-2: Materials for energy generation – Thermal power systems (boiler, turbine, heat exchanger materials); High-temperature alloys, superalloys, and ceramic coatings; Nuclear energy systems – fuel materials, cladding, moderators, structural components, radiation damage, and embrittlement; Materials for renewable generation – solar thermal absorbers, wind turbine composites, and corrosion-resistant materials for hydro and ocean energy.

Module-3: Materials for energy storage – Lithium-ion, sodium-ion, and solid-state battery systems: electrode, electrolyte, separator materials; Supercapacitors: carbon-based and transition metal oxide materials; Hydrogen storage materials – metal hydrides, complex hydrides, and porous materials; Thermal energy storage materials – phase change and sensible heat materials.

Module-4: Materials for energy conversion – Fuel cells (PEMFC, SOFC): membranes, catalysts, electrode materials; Thermoelectric materials – principles, oxide and chalcogenide thermoelectrics, ZT optimization; Piezoelectric and pyroelectric materials for mechanical and thermal energy conversion; Photovoltaic materials – silicon, CdTe, perovskites, and tandem structures. Materials stability, efficiency, and scalability in real-world applications.

Text Books:

1. Kathy Lu, Materials in Energy Conversion, Harvesting, and Storage, Wiley, 2014.
2. Sam Zhang, Materials for Energy, CRC Press (Routledge), 2017.

Reference Books:

3. V. Subramanian, A. K. Shukla, Materials for Energy Storage, Generation and Transport, Springer, 2022.
4. Qiang Xu, Tetsuhi Kobayashi (Eds.), Advanced Materials for Clean Energy, CRC Press (Routledge), 2019.
5. Hieng Kiat Jun, Materials for Energy Conversion and Storage, CRC Press (Routledge), 2022.

Department Elective III

	Powder Metallurgy and Technology	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Introduction and history of powder metallurgy (PM); SWOT analysis of PM; Powder production methods: mechanical processes, atomization, chemical processes, electrochemical processes, and evaporation process; Powder characterization: miniature specimen testing, particle size and shape distribution, electron microscopy of powder, interparticle friction, compression ability, powder structure, chemical characterization, particle packing modifications.

Module-2: Die-compaction: principles, types, deformation mechanism, pressure and stress distribution; Cold isostatic pressing (CIP), cold extrusion, roll compaction; Powder injection molding; Sintering: theory, principles, mechanisms, types, atmospheres, and variables; Liquid phase sintering (LPS); Modern sintering techniques; Defects analysis and structure-property correlation of sintered components.

Module-3: Advanced consolidation routes: hot pressing, hot isostatic pressing (HIP), hot extrusion, hot forging, infiltration, and slip casting; Spark Plasma Sintering (SPS) – principles and applications; Additive manufacturing in PM – Laser Engineered Net Shaping (LENS) and Selective Laser Sintering (SLS); Design and processing advantages of near-net and net-shape technologies.

Module-4: Industrial applications of powder metallurgy: production of filters, gears, carbide tools, tungsten filaments, friction components, porous structures, and self-lubricating bearings; Fabrication of biomaterials and PM components for automotive, aerospace, and medical sectors; Environmental and safety issues in PM industries; Recent advances and current trends in Indian PM industry and global markets.

Text Books:

1. G.S. Upadhyaya, Powder Metallurgy Technology, Cambridge International Science Publishing, 2002.
2. J. S. Hirschhorn: Introduction to Powder Metallurgy, APMI, Princeton, NJ, 1976.

Reference Books:

3. P.C. Angelo and R. Subramanian, Powder Metallurgy: Science, Technology and Materials, PHI Learning, 2008.
4. R.M. German, Powder Metallurgy and Particulate Materials Processing, Metal Powder Industries Federation, 2005.
5. ASM Handbook, Vol 7: Powder Metallurgy, W.B. Eisen (Ed), ASM, 2004.

	Principles & Applications of Additive Manufacturing	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Introduction to Additive Manufacturing (AM): Definition, evolution, advantages, limitations, and classification of AM technologies. Applications across sectors such as automotive, aerospace, biomedical, and tooling. Overview of digital workflow including CAD modeling, reverse engineering, STL file generation, slicing, and AM process chain.

Module-2: Liquid and Solid-Based AM Systems: Stereolithography Apparatus (SLA) – working principle, materials, and applications. Fused Deposition Modeling (FDM) – extrusion process, thermoplastics used, and typical use cases. Key advantages and limitations of both techniques.

Module-3: Sheet and Powder-Based AM Systems: Laminated Object Manufacturing (LOM) – concept and process flow. Selective Laser Sintering (SLS) – laser sintering mechanism, powder requirements, material compatibility, and industrial relevance.

Module-4: Advanced Metal AM Processes: Three-Dimensional Printing (3DP), Laser Engineered Net Shaping (LENS), and Wire Arc Additive Manufacturing (WAAM) – process principles, material systems, and applications. Process selection guidelines and essential post-processing techniques like heat treatment and surface finishing.

Text Books:

1. Ian Gibson, David W. Rosen, and Brent Stucker, Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Springer, 2nd Edition, 2015.
2. Andreas Gebhardt, Understanding Additive Manufacturing, Carl Hanser Verlag GmbH & Co., 2011.

Reference Books:

3. Amit Bandyopadhyay and Susmita Bose, Additive Manufacturing, CRC Press, 2015.
4. Kalpakjian and Schmid, Manufacturing Processes for Engineering Materials, Pearson, 5th Edition, 2008.
5. ASTM F2792 – Standard Terminology for Additive Manufacturing Technologies, ASTM International.

	Non-Destructive Testing	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Introduction to Non-Destructive Testing (NDT): Overview, need, and advantages of NDT methods; classification of NDT techniques; fundamentals of defect detection and evaluation. Visual inspection methods – principles, direct and indirect visual examination tools, borescopes, fiberscopes, and mirrors; criteria for surface discontinuity detection.

Module-2: Eddy Current Testing (ECT): Principle of electromagnetic induction, coil design, conductivity and permeability effects, influencing factors, applications, and limitations. Liquid Penetrant Testing (LPT): Working principle, dye types, developer application, surface preparation, and post-cleaning steps; safety precautions, advantages, and industrial applications.

Module-3: Magnetic Particle Testing (MPT): Concept of magnetic flux leakage, magnetization techniques using yokes and prods, dry and wet methods, particle application, demagnetization methods, and typical defects detected. Radiographic Testing (RT): Principles of X-ray and gamma ray generation, radiographic film systems, exposure techniques, defect identification, image interpretation, and radiation safety guidelines.

Module-4: Ultrasonic Testing (UT): Basic wave propagation, pulse-echo and through-transmission techniques, types of probes and transducers, test set-up and couplants. Applications in flaw detection, thickness measurement, and material characterization. Advanced methods: Phased Array Ultrasonic Testing (PAUT), Acoustic Emission Testing (AET), Magnetic Barkhausen Noise (MBN) technique, and Infrared Thermography for thermal defect mapping.

Text Books:

1. Baldev Raj, T. Jayakumar, M. Thavasimuthu, Practical Non-Destructive Testing, Narosa Publishing House, 3rd Edition, 2015.
2. Ravi Prakash, Non-Destructive Testing Techniques, New Age International, 2010.

Reference Books:

3. Paul E. Mix, Introduction to Nondestructive Testing: A Training Guide, Wiley, 2nd Edition, 2005.
4. R. Hellier, Handbook of Nondestructive Evaluation, McGraw-Hill, 2nd Edition, 2012.
5. ASM Handbook, Volume 17: Nondestructive Evaluation and Quality Control, ASM International, 2002.

Department Elective IV

	Role & Determination of Phase Diagrams	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Basics of thermodynamics relevant to phase equilibria; review of crystal structure, phases, phase diagrams, and thermodynamic equilibrium; laws of thermodynamics; Thermodynamic solution models; concept of chemical potential, Gibbs free energy, phase rule, and lever rule; single component system.

Module-2: Binary phase diagrams—Systems exhibiting complete miscibility, miscibility gaps, eutectic, eutectoid, peritectic, peritectoid, monotectic, and monotectoid reactions; microstructural evolution during solidification and solid-state transformations; Correlation of phase diagrams and thermodynamic state functions.

Module-3: Ternary alloy systems—fundamentals of ternary phase equilibria, isothermal and vertical sections, three-dimensional representations, and interpretation of tie lines and tie triangles; classification of ternary phase diagrams and application of lever rule in ternary systems; significance in complex alloy design and processing.

Module-4: Experimental determination of phase diagrams—cooling curve analysis, static and dynamic methods, use of diffusion couples and metallography; sources of error and uncertainty in experimental phase diagram construction. Applications of phase diagrams in alloy design, processing, and materials selection; limitations of equilibrium diagrams in real-world systems.

Text Books:

1. J.-C. Zhao (Ed.), Methods for Phase Diagram Determination, Elsevier, 2011.
2. F.C. Campbell, Phase Diagrams: Understanding the Concepts, ASM International, 2012.

Reference Books:

3. David A. Young, Phase Diagrams of the Elements, University of California Press, 1991.
4. H. Porter, Phase Transformations in Metals and Alloys, CRC Press, 3rd Edition, 2009.
5. ASM Handbook, Volume 3, Alloy Phase Diagrams, ASM International, 1992.

	Symmetry & Crystallography	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1:

Symmetry, elements of symmetry and symmetry operations associated with each, Eulers construction, interaction of symmetry operations, screw and glide operations

Module-2:

Line lattice, Construction of planar lattice with 2, 3, 4 and 6 fold rotational symmetry, derivations of simple space lattices; Bravais lattices; group theory, point groups and space groups;

Module-3:

Unit cell, basis, crystal structure, quantitative calculations involving the geometry of lattice, visual representation of atomic arrangements of crystals, stereographic projection; determination of point groups of simple crystal structures; Equivalent positions and special positions

Module-4:

naming conventions of crystal structures, classification and various prototypes, Interstitial compounds, Laves phases, super lattice structures and complex stacking sequence

Text Books:

1. Rohrer, Structure and bonding in crystalline materials, Cambridge University Press, 2001
2. G Burns and A M Glazer, Space groups for solid state scientists, Academic Press, 2012

Reference Books:

3. Internal Tables for Crystallography, Vol A, 2005
4. A Kelly and K Knowles, Crystallography and Crystal Defects, 2nd edition, Wiley, 2012
5. M O Keeffe and B G Hyde, Crystal structures I. Patterns and symmetry, Mineralogical Society of America, 1996

	Integrated Computational Materials Engineering	DEC(T)	2-0-0	2 Credits
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Pre-requisites: None

Syllabus:

Module-1: Fundamentals of atomistic and continuum modeling in materials; Introduction to Density Functional Theory (DFT): first-principles calculations, exchange-correlation functionals, electronic structure, and total energy estimation; Basics of Molecular Dynamics (MD): force fields, integration algorithms, boundary conditions, and temperature/pressure control; Applications of DFT and MD in predicting materials behavior – structure-property relationships, defect energetics, diffusion, and thermal properties.

Module-2: Numerical foundations for computational materials science: Introduction to scientific programming and numerical algorithms; Linear system solving methods: Gauss elimination, Gauss-Seidel iteration; Nonlinear system solving: single and multivariable Newton-Raphson methods; Numerical approximation of derivatives and integrals using finite difference and quadrature techniques; Error analysis and convergence behavior in numerical schemes.

Module-3: Monte Carlo (MC) methods in materials science: Metropolis algorithm, Ising model, application of MC for thermodynamic sampling and phase transitions; Molecular Dynamics (continued): time evolution of atomic systems, potential models (Lennard-Jones, EAM), limitations of MD; Multiscale coupling strategies: linking atomistic and mesoscale models to predict bulk properties; Case studies in nanostructured materials, phase stability, and interface behavior.

Module-4: Thermodynamic modeling and mesoscale simulations: Introduction to CALPHAD method – Gibbs energy formulations, assessment techniques, databases, and phase diagram prediction; Simulation of microstructure evolution using Cellular Automata (CA) and Phase Field Modeling (PFM); Applications in solidification, grain growth, spinodal decomposition, and precipitation phenomena; Industrial case studies integrating DFT, CALPHAD, and microstructure simulations in alloy design and process optimization.

Text Books:

1. Press et al., Numerical Recipes: The Art of Scientific Computing (3rd ed.). Cambridge University Press, 2007
2. Richard Lesar, Computational Materials Science, MRS, 2013

Reference Books:

3. K. Ohno et al., Computational Materials Science-From Ab initio to MonteCarlo Methods, Springer, 1999
4. John Zelle, Python Programming: An Introduction to Computer Science, 3rd edition, Franklin Beedle, 2017
5. R J Arsebault et al., Computer Simulation in Materials Science, ASM International, 1986

	Research Methodology and Strategies in English	HEC(T/P)	2-0-0	2 Credits
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	Orientation towards Industrial Practises & Seminar	PCC(P)	2-0-0	2 Credits
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II – Year: I – Semester

	Dissertation Part A	Diss.	13-0-0	13 Credits
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Pre-requisites: None

II – Year: II – Semester

	Dissertation Part A	Diss.	13-0-0	13 Credits
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Pre-requisites: None