COEP Technological University Pune

(A Unitary Public University of Govt. of Maharashtra)

School of Engineering and Technology

Curriculum Structure

Final Year B.Tech.

Metallurgy and Materials Technology

Department of Metallurgy and Materials Engineering

(Effective from: A.Y. 2026-27)

List Of Abbreviations

Abbreviation	Title
AEC	Ability Enhancement Course
BS	Basic Science Course
ESC	Engineering Science Course
PCC	Programme Core Course
PEC	Programme Elective Course
OE/SE	Open/School Elective other than particular program
MDM	Multidisciplinary Minor
VSEC	Vocational and Skill Enhancement Course
HSMC	Humanities Social Science and Management
IKS	Indian Knowledge System
VEC	Value Education Course
RM	Research Methodology
INTR	Internship
PBL	Project
CEA	Community Engagement Activity/Field Project
CCA	Co-curricular & Extracurricular Activities

Final Year B.Tech. Metallurgy and Materials Technology

Semester – VII

Sr. No.	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			Laboratory	
									MSE	TA	ESE	ISE	ESE
1	PCC	*<tbd>*	Corrosion Engineering	2	0	2	1	3	30	20	50	50	50
2	PCC	*<tbd>*	Fatigue, Creep and Fracture Mechanics	2	1	0	1	3	30	20	50	--	--
3	PCC	*<tbd>*	Ceramics and Glasses	2	0	0	1	2	30	20	50	--	--
4	PEC-III	*<tbd>*	Departmental Elective- III	3	0	0	1	3	30	20	50	--	
			1. Advanced Electrochemical Processes										
			2. Surface Treatment Technology										
			3. Nanomaterials & Nanotechnology										
			4. Quantum Materials for Electronics and Energy Applications										
6	MDM-IV	*<tbd>*	Harvesting Energy from Waste	2	0	2	1	3	30	20	50	--	--
7	ELC	*<tbd>*	Research Methodology	2	0	0	1	2	30	20	50	--	--
8	ELC	*<tbd>*	Project Stage -III	0	0	10	0	5	---	--	--	50	50
9	ELC	*<tbd>*	Internship	0	0	6	0	1	--	--	--	CIE: 100	
			Total	**13**	**1**	**20**	**6**	**22**					

Legends: L-Lecture, T-Tutorial, P-Practical, S-Self Study (topics specified in the syllabus or given by subject co-ordinator), Cr-Credits ISE-In-Semester- Evaluation, ESE-End-Semester-Evaluation, MSE-Mid-Semester Evaluation, TA- Teachers' Assessment, CIE-Continuous-Internal-Evaluation

Final Year B.Tech. Metallurgy and Materials Technology

Semester – VIII*

Sr. No	Course Type	Course Code	Course Name	L	T	P	S	Cr	Evaluation Scheme (Weightages in %)				
									Theory			**Laboratory**	
									MSE	TA	ESE	ISE	ESE
1	PEC-IV	*<tbd>*	**Departmental Elective- IV***	3	0	0	1	3	30	20	50	--	--
			1. Advanced Manufacturing Processes										
			2. Tribology of Materials										
			3. Bio Materials										
			4. Advanced Materials for semiconductors and Batteries										
2	PEC-V	*<tbd>*	**Departmental Elective-V***	3	0	0	1	3	30	20	50	--	--
			1. Mechanical Behaviour of Materials										
			2. Smart Materials										
			3. Light Metals and Alloy										
			4. Electronic and Magnetic Materials										
3	PEC-VI	<tbd>	**Departmental Elective- VI***	3	0	0	1	3	30	20	50	--	--
			1. Sustainable Processes										
			2. Crystallographic Texture in Materials										
			3. High Entropy Alloys										
			4. Design & Selection of Materials										
4	ELC	<tbd>	Internship / Industry Preplacement /	0	0	6	0	3	--	--	--	50	50
			Total	**9**	**0**	**6**	**3**	**12**					

Legends: L-Lecture, T-Tutorial, P-Practical, S-Self Study (topics specified in the syllabus or given by subject co-ordinator), Cr-Credits ISE-In-Semester- Evaluation,
ESE-End-Semester-Evaluation, MSE-Mid-Semester Evaluation, TA-Teachers' Assessment,
CIE-Continuous-Internal-Evaluation

* Students pursuing off-campus internships in Semester VIII are required to complete the prescribed MOOC courses corresponding to the Departmental Electives, in consultation with their Faculty Advisor, in accordance with the Internship Guidelines.

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Course: Corrosion Engineering

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	2-0-0-1 = 2	**MSE and TA**	30 and 20
Credits	2	**ESE**	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Remember and understand concepts and fundamentals in corrosion.
2. Apply knowledge of material selection for different corrosive environments.
3. Apply knowledge of corrosion prevention methods, testing methods and standards.
4. Analyze electrochemical behavior and different forms of corrosion in engineering materials.
5. Evaluate corrosion problems and recommend suitable protection methods.
6. Create and propose suitable corrosion mitigation and surface protection strategies.

Syllabus

Unit	Contents	Lecture
01	**Fundamentals of Corrosion and Electrochemical Principles** Importance and economic impact of corrosion, Thermodynamics and kinetics of electrode processes, Free energy concept, EMF series, electrochemical cell analogy, anodic and cathodic reactions, determination of corrosion tendency of metals, Nernst equation and its applications, galvanic series, concept of over-potential, polarization, Evans corrosion diagram, mixed potential theory, kinetics of passivity and transpassivity, Pourbaix diagram for metal-water systems, applications and limitations. **Self-Study Topics:** Industrial corrosion failures and their economic impact, applications of Pourbaix diagrams in material selection, recent developments in electrochemical corrosion monitoring techniques.	**06**
02	**Forms and Mechanisms of Corrosion** Various forms of corrosion such as uniform corrosion, galvanic corrosion, crevice corrosion, pitting corrosion, filiform corrosion, intergranular corrosion, selective leaching, erosion corrosion, fretting corrosion, cavitation damage, environmentally assisted cracking (EAC) including stress corrosion cracking (SCC), corrosion fatigue, hydrogen embrittlement and microbiologically influenced corrosion (MIC).	**06**

	Self-Study Topics: Corrosion in aerospace and marine industries, corrosion behavior of stainless steels and aluminium alloys, role of microorganisms in industrial corrosion.	
03	**Corrosion Prevention Methods** Principles of corrosion protection, material selection, environmental modification, design for corrosion prevention, corrosion inhibitors, cathodic and anodic protection, classification and principles of metallic, organic and inorganic coatings, surface engineering approaches for corrosion resistance, high-temperature oxidation and corrosion. **Self-Study Topics:** Smart coatings and nano-coatings for corrosion protection, green corrosion inhibitors, corrosion protection techniques for pipelines and offshore structures.	**06**
04	**Corrosion Testing, Standards and Industrial Applications** Principles of corrosion testing and evaluation, overview of physical and electrochemical corrosion testing methods, corrosion rate measurements, interpretation of polarization behavior, significance of salt spray and cyclic corrosion tests, intergranular corrosion testing of stainless steels, introduction to ASTM and NACE standards, corrosion considerations in marine, petrochemical, chemical and high-temperature industries, case studies on corrosion failures and prevention. **Self-Study Topics:** Recent ASTM and NACE standards for corrosion testing, corrosion monitoring techniques in industries, industrial case studies on corrosion failure analysis.	**06**

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Course: Corrosion Engineering Laboratory

Course Code		**Scheme of Evaluation**	ISE AND ESE
Teaching Plan	0-0-2-0 = 2	**ISE**	50
Credits	1	**ESE**	50

Course Outcomes:

At the end of the laboratory work, students will demonstrate the ability to:

1. Remember and understand concepts and fundamentals in corrosion.
2. Apply knowledge of theory to conduct actual practical independently.
3. Analyse and interpret results obtained in experiments.
4. Evaluate corrosion-related numerical problems and experimental data.
5. Create and suggest suitable corrosion prevention methods and surface protection strategies.

List of Experiments:

A Set of 08 Number of Experiments Based on the Theory Syllabus:

1. Measurement of potential of various metals (Fe, Cu, Zn etc.)
2. pH measurement
3. Crevice corrosion in stainless steel
4. Intergranular corrosion of austenitic stainless steel
5. Use of inhibitors in preventing corrosion
6. Hot dip zinc coating for corrosion prevention
7. Weight loss method for corrosion rate determination
8. Salt spray exposure
9. Cyclic corrosion test
10. Stress corrosion cracking (U bend test); Stress corrosion cracking of Mg/Mg alloys in NaCl exposed at different time intervals
11. Polarization and Electrochemical Impedance Study
12. Characterization by optical microscopy, SEM and XRD methods
13. Effect of machining on microstructure and corrosion behaviour

Textbooks

1. Corrosion Engineering, 3rd ed., Tata McGraw Hill, 2008.
2. Corrosion and Corrosion Control, 4th ed., Wiley Interscience, 2008.

Reference Books

1. Principles and Prevention of Corrosion, 2nd ed., Prentice Hall International, 1995.
2. Corrosion Volume I and II, Butterworth Publications, London, 1994.
3. ASM Handbook Volume 13A: Corrosion – Fundamentals, Testing and Protection, ASM International, 2010.
4. ASM Handbook Volume 13B: Corrosion – Materials, ASM International, 2010.

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Course: Fatigue, Creep and Fracture Mechanics

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	2-1-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Identify failure modes and analyze the reasons of failures of the components in service.
2. Understand macro and microscopic aspects of fracture mechanisms
3. Understand significance of the failure analysis techniques.
4. Understand fracture mechanic approach

Syllabus:

Unit	Contents	Lecture
01	**Fundamentals of fracture mechanics** An atomic view of fracture, Theoretical cleavage strength, Griffith's theory of fracture, Strain energy release rate, Plastic zone ahead of a crack tip, plain strain fracture toughness (K_{IC}), Crack Tip Opening Displacement, Strength of materials vs. fracture mechanics approach to engineering design.	**04**
02	**Fracture Mechanisms in Metals:** Types of fracture, Fracture Mechanisms in Metals: Ductile Fracture - Void Nucleation, Growth and Coalescence, Brittle fracture- cleavage initiation and fracture, Combined fracture modes, Inter granular fracture, Ductile - Brittle Transition, Alloy design for fracture resistance.	**06**
03	**Fatigue:** Low cycle fatigue, Effect of mean stress and metallurgical factors on fatigue life, Micro structural aspects of fatigue failure, Cumulative fatigue damage estimation, Use of fracture mechanics to study fatigue crack propagation, Methods for improving fatigue life.	**06**
04	**Creep:** Temperature - stress- strain relations, Creep life estimation, Deformation mechanism maps, Creep fracture micro mechanisms, Creep- fatigue interactions, Alloy design for creep resistance.	**08**

05	**Types of failure** Stress systems related to single load fracture of ductile and brittle metals, residual stresses, distortion, wear, electrochemical and high temperature corrosion failures.	**06**
06	**Failure case studies**- shafts and gears, bearings, mechanical fasteners, welded and cast structures, failure analysis methodology and techniques.	**06**

Textbooks:

1. Donald J. Wulpi, "Understanding How components fail", Third Edition ASM International, USA. ISBN : 978- 1-62708- 014 - 9, 2013
2. Dieter, G.E., "Mechanical Metallurgy", Third Edition, McGraw- Hill Education Pvt Ltd, New Delhi (India), 2017, ISBN:978-1259064791

Reference Book:

1. T. L. Anderson, " Fracture Mechanics: Fundamentals and Applications", Third Edition, CRC Press, USA, 2005, ISBN : 978-1-4200-5821-5 (eBook - PDF)
2. Metals Hand Book, Vol 11, "Failure Analysis and Prevention", ASM International 1996, ISBN: 978-1-62708-293-8
3. Proceedings of the Indian Academy of Sciences, Engineering Sciences, Vol 3 (12) Part 4 Dec 1980 and Vol 4 (13) Part1,April 1981 Published by The Indian Academy of Sciences, Bangalore, India

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Course: Ceramics and Glasses

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	2-0-0-1 = 2	**MSE and TA**	30 and 20
Credits	2	**ESE**	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Classify ceramic and glass materials based on composition and structure.
2. Analyse processing techniques and their influence on properties.
3. Explain deformation, fracture, and thermal behaviour of brittle materials.
4. Select suitable ceramic or glass materials for engineering applications.
5. Discuss recent developments in advanced ceramics and specialty glasses.

Syllabus:

Unit	Contents	Lecture
01	**Introduction to Ceramics and Glasses** Fundamental nature of ceramic and glass materials: Definition and classification of ceramics and glasses, Traditional vs advanced ceramics, Atomic bonding and crystal structures, Ceramic crystal systems: silicates, oxides, carbides, nitrides; Amorphous structure of glasses, Structure–property relationships.	**04**
02	**Processing of Ceramics and Glasses** **Ceramics:** Raw materials and major powder preparation methods, forming methods: pressing, slip casting, extrusion, tape casting, CIP, HIP; Drying and sintering, Solid-state and liquid-phase sintering, Grain growth and Ostwald ripening, pore-grain boundary interactions, Reaction sintering, sintering of nanomaterials, Additive manufacturing of ceramics (introductory concepts) **Glasses:** Glass additives, Glass smelting and refining, Float glass process, Annealing and tempering, Fiber and specialty glass manufacturing.	**06**
03	**Properties and Characterization** Mechanical behaviour of ceramics, Brittleness and fracture mechanics, Thermal properties: thermal shock, expansion, refractoriness, Electrical and dielectric behaviour, Optical properties of glasses, Corrosion and chemical durability, Correlation of properties with structure and defects. compressive strength, 3–4-point bend test and Weibull modulus.	**06**

04	**Engineering Ceramics and Functional Glasses** **Advanced Ceramics:** Alumina, zirconia, silicon carbide, silicon nitride; Piezoelectric and ferroelectric ceramics; Bioceramics and coatings; Refractory ceramics, nanoceramics, transparent ceramics, Applications of Ceramic components in aerospace, automotive, electronics, solid-state batteries and energy sectors, **Functional Glasses:** Optical fibers, Bioactive glasses, Glass ceramics, Smart and display glasses.	**08**

Text Books:

1. C. Barry Carter, M. Grant Norton, Ceramic Materials- Science and Engineering, Second Edition, Springer New York, 2013
2. M. N. Rahaman, Ceramic Processing and Sintering, 2nd edition, Marcel Dekker Inc., NY, 2003.
3. W.D. Kingery, H.K. Bowen and D.R. Uhlman, Introduction to Ceramics, Ceramic Science and Technology, John Wiley and Sons, Singapore, 1991.
4. M.W. Barsoum, Fundamentals of Ceramics, 2nd edition, IoP Publications, UK, 2003
5. James E. Shelby, Introduction to Glass Science and Technology" 3rd Ed., Royal Society of Chemistry, 2020.

Reference Books:

1. Engineered Materials Handbook, Volume 4: Ceramics and Glasses, ASM International, 1991.

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Course: Advanced Electrochemical Processes

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcomes:

At the end of course students will be able to:

1. Identify methods of electrochemical cell for metal / nonmetal extraction
2. Explain the effect of electrochemical cell parameters
3. Apply thermodynamic and kinetic principles for cell improvement
4. Analyse secondary sources for recycle reuse and circular economy
5. Evaluate sustainability of process on energy and carbon footprint
6. Design electrochemical system for extraction

Syllabus:

Unit	Contents	Lectures
01	**Electrochemical basics:** Electrochemical cells; Electrode potential; Nernst equation; Faraday's laws of electrolysis Conductance of electrolytes; Ionic transport in molten salt; Overvoltage and polarization; thermodynamics and kinetics	06
02	**Principles of electrochemical cell:** Electrolysis fundamentals; Electro-winning; Electro-refining; Electro-deposition; Current efficiency; Energy consumption in electrolytic processes; Electrode reactions and kinetics; Mass balance; Heat balance, Cell voltage calculation, Current efficiency calculation; Power consumption, Electrode consumption estimation.	06
03	**Extraction of metals and critical minerals:** Aluminium: Bayer process, Hall–Héroult process, Carbon anode reactions, Aluminium refining, Magnesium: Electrolytic extraction, Thermal reduction methods. Sodium and Potassium, Downs cell, Fused salt electrolysis. Rare Earth Metals- REE extraction, Molten fluoride electrolysis, Molten oxide electrolysis.	06

04	**Process design:** Bath composition selection; Cell design and operation; electrode selection, Temperature effects; Rare earth molten salt systems such as Al_2O_3–Cryolite, NdF_3 – LiF, $MgCl_2$-based melts, etc, Application of Phase diagrams for selection of molten electrolytes.;	**06**
05	**High purity metals:** Challenges in high purity metal production; raw material preparation, Applications area for high purity metals such as Ca, Mn, Na, Mg, Cr, etcS	**06**
06	**Environmental impact and green technology:** Secondary and tertiary sources; Electronic waste, Consumer goods, Industrial sludge, Industry spent solution, etc Decarburisation, climate and environmental protection; reduction of carbon footprints; green technology, use of renewal energy, clean energy for metal production, case studies.	**06**

Textbooks:

1. V. S. Bagotsky, Fundamentals of electrochemistry,Second Edition (2006)
2. M. Shamsuddin, Physical Chemistry of Metallurgical Processes, Wiley Publications, First Edition (2016)
3. C.K.Gupta, N.Krishnamurthy, Extractive Metallurgy of Rare Earths, CRC Press, First edition (2005)

Reference Books:

1. Grjotheim, K., and Kvande, H., Introduction to Aluminium Electrolysis: Understanding the Hall–Heroult Process, 3rd Edition,
2. Gupta, C. K., and Krishnamurthy, N., *Extractive Metallurgy of Rare Earths*, CRC Press, Boca Raton, Florida.
3. Bard, A. J., and Faulkner, L. R., *Electrochemical Methods: Fundamentals and Applications*, 2nd Edition, John Wiley & Sons, New York.

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Course: Surface Treatment Technology

Course Code		Scheme of Evaluation	MSE, TA, and ESE
Teaching Plan	3-0-0-1=3	MSE and TA	30 and 20
Credits	3	ESE	50

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Explain the importance of surface engineering in enhancing material performance.
2. Describe various surface modification and coating techniques.
3. Analyse process parameters affecting coating characteristics and performance.
4. Select appropriate surface treatment methods for engineering applications.
5. Evaluate coating properties using characterization and testing techniques.
6. Apply surface treatment technologies in mechanical, metallurgical, electronic and biomedical industries.

Syllabus:

Unit	Contents	Lectures
01	**Fundamentals of Surface Treatment:** Introduction to surface engineering and surface treatment technology, Importance of surface-engineered materials in modern engineering, Surface-dependent properties: mechanical, chemical, thermal, electrical, electronic and optical properties, Wear, corrosion, fatigue and abrasion resistance through surface treatment, Role of coatings and surface modification in improving component life and performance, Classification of surface treatment processes	06
02	**Surface Preparation and Surface Modification Techniques:** Importance of substrate preparation. Surface cleaning and pretreatment methods: (Physical methods, Chemical methods, Electrochemical methods). Mechanical surface modification techniques (Shot Peening, Laser Shock Peening). Thermal surface modification techniques, Ion implantation process, Laser surface processing, Electron beam surface treatment methods Plasma Surface Modification (Nitriding, Carburizing)	06
03	**Thin Film Deposition Technologies:** Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), Atomic layer deposition (ALD), Electroplating and electro deposition techniques, Electroless deposition methods, Wetting-based coating deposition techniques, thin film deposition processes for electronic materials	06

04	**Advanced Coating Technologies:** Thermal spray coating methods, Plasma coating processes, Spark discharge coating processes, Organic and powder coatings, Thermal barrier coatings, Smart coatings, Nanostructured coatings, Coatings for high temperature applications, Coating on plastics and non-metallic substrates, Product-oriented coating technology and selection criteria	**06**
05	**Coating Systems, Process Parameters and Applications:** Coating systems and functions of coating layers, Substrate technology and coating adhesion, Process parameters affecting coating quality and deposition yield, Surface properties of coatings: Wear resistance, Corrosion resistance, Thermal stability and their applications in: Electronics and optical industries, Energy and automotive sector, Surgical instruments, medicine and biotechnology	**06**
06	**Characterization and Evaluation of Coatings:** Physical and mechanical characterization of coatings, Surface morphology and microstructural analysis, Coating thickness measurement techniques, Adhesion and bond strength testing, Hardness and surface roughness testing, Wear and corrosion testing methods, non-destructive evaluation techniques, Performance evaluation and failure analysis of coatings	**06**

Textbooks:

1. Surface Engineering for Corrosion and Wear Resistance- J.R. Davis
2. Introduction to Surface Engineering and Functionally Engineered Materials-Peter Martin
3. Surface Engineering: Theory and Applications- T.S. Sudarshan
4. Thin Film Phenomena-K.L. Chopra
5. Principles of Metal Surface Treatment and Protection- D R Gabe
6. Modern Surface Technology- F.W. Bach, K. Möhwald, and A. Laarmann

Reference Books:

1. Handbook of Thermal Spray Technology- ASM International
2. Materials Science of Thin Films- Milton Ohring
3. Plasma Surface Engineering-M. Ohring
4. Coatings Technology Handbook-Arthur A. Tracton

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Course: Nanomaterials and Nanotechnology

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome (COs):

At the end of this course, the students will demonstrate the ability to:

1. Explain fundamental concepts of nanoscale materials, surface chemistry, and size-dependent properties of nanomaterials.
2. Design and select appropriate synthesis methods for specific nanomaterial applications, with their mechanistic understanding.
3. Apply advanced characterization techniques to analyse nanomaterial process-structure-property relationships.
4. Analyse real-world applications of nanomaterials in semiconductors, energy, catalysis, and biomedical domains.
5. Evaluate material selection criteria and sustainability considerations for industrial-scale nanomaterial production.
6. Design solutions for nanomaterial-related engineering problems considering cost, scalability, and environmental impact.

Syllabus:

Unit	Contents	Lectures
01	**Introduction to nanomaterials:** Introduction to nanomaterials and nanotechnology: Significance of nanoscale and technology, Historical development, Classification of nanomaterials, Length scales, Surface area/volume ratio of nanoscale materials, Size and dimensionality (0D, 1D, 2D, 3D nanostructures), Surface energy and aggregation, Thermodynamic vs kinetic stability **Self-Study:** Bio-inspired nanomaterials	**06**
02	**Synthesis and processing of nanomaterials:** Top-down and Bottom-up approaches for synthesising various 0D, 1D, 2D and 3D nanomaterials, Specific materials synthesis: CNT, graphene, QD, metal nanoparticles, nanofibers, semiconductor oxide nanostructures, thin films; Classifying methods with solution-based vs solid state processing, Self-assembly, Green synthesis, template-directed synthesis, microwave-assisted synthesis, surface modification, factors affecting during synthesis of nanomaterials; Mechanism of synthesis: Nucleation and growth mechanisms, Ostwald ripening, Gibbs-Thomson effect, La-Mer’s model, Scalability and industrial synthesis, Batch vs continuous production. **Self-Study:** Green synthesis of nanomaterials using plant extract	**06**

03	**Nanomaterials Structure-Property relationships:** Mechanical property variations with size and shape, Thermal properties and phonon scattering, Optical and photonic properties, Quantum confinement effects, Plasmonic properties, Electrical and electronic properties, Single electron tunnelling, Magnetic and superparamagnetic behaviour, Chemical reactivity and catalytic activity, Biocompatibility and cellular interactions. Effect of synthesis process parameters on properties of nanomaterials. **Self Study:** Effect of particle size on optical properties of nanomaterials	**06**
04	**Nanomaterials characterization:** Structural characterization, Size and morphology analysis, Compositional and surface analysis, Optical and physical properties, Advanced techniques: in-situ characterization, electron tomography, SERS, correlative microscopy; Design of characterization strategies, Quantitative vs qualitative analysis methods. **Self Study:** Fundamentals of electron microscopy	**06**
05	**Applications of Nanomaterials:** Semiconductors and electronics, Energy storage and conversion, batteries, Catalysis and chemical processing, Biomedical applications, Materials and manufacturing, Environmental applications, Case studies of industrial nanomaterial implementations. **Self Study:** Nanomaterials in energy storage applications	**06**
06	**Ethics, Safety, and Societal Impact:** Nanotoxicology and safety protocols, Environmental and health impacts, Regulatory frameworks, Life cycle assessment and end-of-life management, Industrial scalability and economic factors, Quality control and standardization, technical challenges; Ethical and societal aspects; Responsible innovation, India-specific nanotechnology initiatives, Future trends: AI, Industry 4.0, robotics, quantum, sustainable nanotechnology, Market projections and career pathways **Self Study:** Regulatory frameworks associated with nanomaterials	**06**

Textbooks:

1. Rajendra Kumar Goyal," Nanomaterials and nanocomposites: Synthesis, Properties, Characterization Techniques and Applications" CRC Press, 2017, ISBN: 978-14987616662017.
2. Lindsay, S. M., *Introduction to Nanoscience*, Oxford University Press, New York, 2010.
3. B.S. Murty, P. Shankar, Baldev Raj, B B Rath, James Murday, "Textbook of Nanoscience and Nanotechnology", 2013, University Press (I) Pvt. Ltd. (e-ISBN:978-3-642-28030-6).

Reference Books:

1. Schodek, Daniel L., Paulo Ferreira, and Michael F. Ashby. Nanomaterials, nanotechnologies and design: an introduction for engineers and architects. Butterworth-Heinemann, 2009.
2. Bhushan, Bharat, ed. Springer handbook of nanotechnology. Springer, 2017.
3. Rao, CN Ram, and A. Govindaraj. Nanotubes and nanowires. Royal Society of Chemistry, 2015
4. Mirkin & Niemeyer (Eds.), Nanoscience and Nanotechnology, Wiley-VCH, 2nd Edition, 2010

Final Year B.Tech. Metallurgy and Materials Technology

Course: Quantum Materials for Electronic and Energy Applications

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcomes

1. Explain the fundamental concepts of quantum materials, quantum mechanics, and the electronic structure of solids.
2. Describe the electronic properties of quantum materials, including charge transport, density of states, quantum confinement, and low-dimensional systems.
3. Illustrate the properties and applications of quantum materials in modern electronic and optoelectronic devices.
4. Analyze the role of quantum materials in energy conversion and storage technologies, including solar cells, batteries, supercapacitors, and fuel cells.
5. Identify appropriate synthesis and characterization techniques for quantum materials based on their structural and functional properties.
6. Evaluate emerging quantum materials and their potential applications in sustainable electronics, clean energy, and next-generation technologies.
7.

Syllabus:

Unit	Contents	Lectures
01	**Foundations of Quantum Materials:** Introduction to quantum materials; limitations of classical theories; development of quantum theory; wave-particle duality; de Broglie hypothesis; Schrödinger equation (concept); crystal structures; electronic structure of solids; energy band formation; conductors, semiconductors, and insulators.	06
02	**Electronic Properties of Quantum Materials:** Free electron model; density of states (concept); Fermi energy and Fermi–Dirac distribution; electronic transport in solids; quantum confinement; quantum wells, quantum wires, quantum dots; band-gap engineering; low-dimensional materials.	06
03	**Quantum Materials for Electronic Applications:** Graphene and other two-dimensional materials; topological insulators (introduction); magnetic quantum materials; spintronics (basic concepts); superconductivity (introduction); applications in transistors, sensors, memory devices, LEDs, lasers, and flexible electronics.	06

04	**Quantum Materials for Energy Applications:** Quantum materials for photovoltaic devices; perovskite and quantum dot solar cells; thermoelectric materials; photocatalytic materials; hydrogen production; electrocatalysts; materials for lithium-ion, sodium-ion, and solid-state batteries; supercapacitors; fuel cells.	**06**
05	**Synthesis and Characterization of Quantum Materials:** Synthesis of quantum materials; solid-state reaction; sol-gel process; hydrothermal synthesis; chemical vapor deposition (CVD); thin-film deposition; characterization techniques including X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Raman spectroscopy, UV–Visible spectroscopy, and electrical and magnetic property measurements.	**06**
06	**Emerging Quantum Materials and Future Technologies** Quantum computing materials (overview); quantum sensors; quantum communication materials; wearable and flexible electronics; sustainable quantum materials; challenges in large-scale manufacturing; recent advances in quantum materials for electronics and clean energy; future prospects and industrial applications	**06**

Text Books:

1. Eisberg, Robert M., and Robert Resnick. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles. Wiley, 1985. ISBN: 9780471873730.
2. Shankar, Ramamurti. Principles of Quantum Mechanics. Springer, 2008.
3. Kittel, C., Introduction to Solid State Physics, 8th Edition, John Wiley & Sons, New York, 2005.
4. Streetman, B. G., and Banerjee, S. K., Solid State Electronic Devices, 7th Edition, Pearson Education, 2015.
5. Kasap, S. O., Principles of Electronic Materials and Devices, 4th Edition, McGraw-Hill Education, New York, 2018.
6. Eisberg, R., and Resnick, R., Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, 2nd Edition, John Wiley & Sons, New York, 1985.

Reference Books:

1. Callister, W. D., Jr., and Rethwisch, D. G., Materials Science and Engineering: An Introduction, 10th Edition, John Wiley & Sons, New York, 2018.
2. Cao, G., and Wang, Y., Nanostructures and Nanomaterials: Synthesis, Properties and Applications, 2nd Edition, World Scientific Publishing, Singapore, 2011.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Harvesting Energy from Waste

Course Code		**Scheme of Evaluation**	MSE, TA, and ESE
Teaching Plan	2-0-2-1=3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of the course, students will demonstrate the ability of:

1. The project-based learning course enables students to apply concepts from Waste Management
2. Understand waste-to-energy (WtE) conversion technologies and principles.
3. Apply various approaches for energy conversion and evaluate the feasibility of WtE systems.
4. Develop and present solutions for real-world waste-to-energy projects and environmental impact mitigation.

Syllabus:

Unit	Contents	Lectures
01	**Introduction to Waste-to-Energy (WtE) Technologies** Section provides the foundation for understanding how municipal solid waste, industrial waste, and other residues can be converted into useful energy forms such as electricity, heat, or transportation fuels. It covers the global context of waste management, the shift toward a circular economy, and the role of WtE in reducing landfill dependence.	**07**
02	**Energy Recovery from Biomass and Organic Waste** This focuses on biological conversion processes: **Anaerobic Digestion:** Breaking down organic waste (food scraps, animal manure) in the absence of oxygen to produce biogas (rich in methane), which can be used for cooking, heating, or electricity. **Biofuels:** Converting biomass into liquid fuels like ethanol or biodiesel through fermentation or chemical processes.	**07**
03	**Pyrolysis and Gasification** These are thermochemical conversion processes that operate at high temperatures: **Pyrolysis:** The thermal decomposition of waste in the *complete absence* of oxygen. It produces pyrolysis oil (bio-oil), syngas, and char, which can be refined for various industrial uses. **Gasification:** The thermochemical conversion of waste using *limited* amounts of oxygen or steam at very high temperatures. It produces "syngas" (a mixture of hydrogen and carbon monoxide), which is a versatile fuel for power generation or chemical synthesis	**07**

04	**Incineration for Energy Recovery and Emission Control** **Incineration (Combustion):** Burning waste in a controlled furnace to produce heat. This heat boils water to create steam, which drives a turbine to generate electricity. **Emission Control:** Because incineration produces flue gases, particulate matter, and harmful pollutants (like dioxins), this topic covers advanced technologies like **scrubbers, baghouse filters, and electrostatic precipitators** to clean the exhaust and ensure environmental compliance.	**07**
05	**Project Design and Feasibility Studies** Before building a facility, engineers must evaluate if the project is viable: **Technical Feasibility:** Determining if the technology matches the composition and volume of the available waste. **Economic/Financial Analysis:** Calculating the Capital Expenditure (CAPEX), Operational Expenditure (OPEX), and the potential Return on Investment (ROI) based on energy sales and tipping fees. **Environmental Impact Assessment (EIA):** Analyzing potential impacts on air quality, water, and surrounding communities to ensure the project meets legal and sustainability standards.	**08**

Textbooks:

3. Rogoff, M. J., & Screve, F. Waste-to-Energy: Technologies and Project Implementation. Elsevier, 2011.
4. Niessen, W. R. Combustion and Incineration Processes: Applications in Environmental Engineering. CRC Press, 2010.
5. Klinghoffer, N. B. Waste to Energy Conversion Technology. Woodhead Publishing, 2013.
6. Sharma, M. Energy Recovery from Organic Waste: Thermochemical and Biochemical Processes. CRC Press, 2017.
7. Nabavi, A. Sustainable Waste-to-Energy: Life Cycle Assessment and Economical Metrics. Elsevier, 2022.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Research Methodology

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	2-0-0-1=2	**MSE and TA**	30 and 20
Credits	2	**ESE**	50

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Formulate research problems by defining objectives, hypotheses, variables, and feasibility.
2. Synthesize literature using reproducible search and screening strategies.
3. Apply research ethics, authorship norms, compliance rules, and FAIR data practices.
4. Produce research outputs through ethical analysis, documentation, and dissemination.

Syllabus:

Unit	Contents	Lecture
01	**Introduction to Research:** What is scientific research? The objectives of research, motivation, types of research, research approaches, research methodology, significance of research, and indications of good research	**04**
02	**Designing Problem Statement and Experimentation Plan:** What are the research problems? Literature review, formulation of a feasible problem, hypothesis, errors in problem selection, tabulation of relevant data from literature, selection of variables, and flow chart of experimental plan	**04**
03	**Methods- Simulations and Experiments:** Conventional approaches, selection of tools, setting up production, validation of results, performance analysis, sensitivity analysis, errors in measurements. RCR and Ethics:Responsible conduct of research, IEC compliance, what is plagiarism, QRPs, generative A.I. in research	**08**
04	**Statistics and Uncertainty Quantification:** Data, importance of analyzing data, types of analyses, selection practices, statistics, sampling techniques, uncertainty quantification, errors analysis, Design of Experiments. IPR, Research Ethics and Publishing: Introduction to IPR, significance of IPR, types of IPR, recent developments, technical writing, and aspects important for publishing in Q1/Q2 journals	**08**

Text Books:

1. Melville, S., & Goddard, W. (1996). Research methodology: An introduction for science & engineering students. Juta & Co.

2. Kothari, C. R. (2009). Research methodology: Methods and trends. New Age International Publishers.
3. Goddard, W., & Melville, S. (2001). Research methodology: An introduction (2nd ed.). Juta Academic.
4. Kumar, R. (2005). Research methodology: A step-by-step guide for beginners (2nd ed.). Sage Publications.
5. Sharma, S. D. (2001). Operational research. Kedar Nath Ram Nath & Co.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Project Stage III

Course Code		Scheme of Evaluation	ISE and ESE
Teaching Plan	0-0-10-0 = 5	ISE	50
Credits	5	ESE	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Integrate and synthesize project work across Stages I, II, and III, consolidating research findings, design implementations, and results into a comprehensive project report demonstrating progression from conception to final execution.
2. Analyze project methodology and outcomes through technical presentation, effectively communicating research approach, findings, and contributions to expert panel and departmental audience.
3. Evaluate project quality through rigorous assessment by expert panels (project guide, external examiner, and faculty members), demonstrating professional standards and readiness for academic/industrial scrutiny.
4. Disseminate knowledge through publication of project outcomes in peer-reviewed journals (Scopus/SCI/WoS indexed) or through Intellectual Property Rights (IPR) filing, contributing to advancement of the discipline.
5. Demonstrate project outcomes through department-level exhibition, effectively showcasing project artifacts, prototypes, or research results to diverse stakeholders including faculty, peers, and external evaluators.

Scope (TRL-4)

Continuation of Project-II, Experimentation, Results analysis, Proof of concept, Project report writing, Publications in Journal, IPR

Final Year B.Tech. Metallurgy and Materials Technology

Course: Internship

Course Code		**Scheme of Evaluation**	CIE
Teaching Plan	0-0-6-0 = 1	**ESE**	100
Credits	1		

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Apply metallurgical and materials engineering knowledge for the development of innovative solutions, product improvement, prototyping, or process optimization.
2. Transform proof-of-concept ideas from Project Stage-III into scalable models, industrial applications, or start-up-oriented solutions.
3. Acquire and demonstrate proficiency in modern engineering tools, research methodologies, and industrial practices relevant to advanced materials and manufacturing sectors.
4. Apply critical thinking, experimentation, and data interpretation techniques to analyze and solve complex industrial or research problems.
5. Exhibit professional ethics, effective communication skills, teamwork, leadership qualities, and adaptability in industrial, research, or international work environments.
6. Prepare and present comprehensive technical reports, project documentation, and presentations demonstrating the outcomes, innovations, and learning achieved during the internship.

Nature of Internship

Industry / R and D labs / Education institutes (HEI less than 100 NIRF rank)

Scope of internship

This should be decided by the nature of Project-I selected by the group of 5th-semester students. A project guide should assist in grooming the student group in relevant areas to enhance their knowledge and skills.

Final Year B.Tech. Metallurgy and Materials Technology

Semester VIII

Course: Advanced Manufacturing Processes

Course Code		**Scheme of Evaluation**	MSE, TA, and ESE
Teaching Plan	3-0-0-1=3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of this course, the students will be able to:

1. Understand modern and advanced manufacturing techniques relevant to metallic and advanced materials.
2. Explain processing–microstructure–property relationships during manufacturing.
3. Develop understanding of additive manufacturing, advanced joining, severe plastic deformation, and surface engineering.
4. Select processes for various industrial applications.
5. Characterize and understand quality evaluation methods for advanced manufacturing methods.

Syllabus:

Unit	Contents	Lecture
01	**Introduction to Advanced Manufacturing:** Need for advanced manufacturing, Limitations of conventional manufacturing, Material–process–property relationship, Manufacturing for advanced materials, Precision, sustainability, and Industry 4.0 concepts, Hybrid manufacturing systems	**06**
02	**Advanced Metal Casting and Solidification Processing:** Rapid solidification processing, Directional solidification, Vacuum casting, Investment casting, Squeeze casting, Semi-solid metal processing, Solidification microstructures, Defects and control	**06**
03	**Advanced Metal Forming and Severe Plastic Deformation:** High strain-rate forming, Hydroforming, Electromagnetic forming, Superplastic forming, Severe Plastic Deformation (SPD): ECAP, High Pressure Torsion (HPT), Accumulative Roll Bonding (ARB), Ultrafine-grained materials	**08**
04	**Advanced Joining Processes:** Friction Stir Welding (FSW), Diffusion bonding, Laser welding, Electron beam welding, Ultrasonic welding, Brazing of advanced materials, Joining of dissimilar materials.	**06**

05	**Non-Traditional Machining Processes:** Electrical Discharge Machining (EDM), Wire EDM, Electrochemical Machining (ECM), Laser Beam Machining (LBM), and Electron Beam Machining (EBM), Abrasive Water Jet Machining (AWJM), and Ultrasonic Machining (USM).	**05**
06	**Additive Manufacturing of Materials:** Fundamentals of Additive Manufacturing (AM), classifications, Metal additive manufacturing, Powder characteristics, Process parameters, Residual stresses, Defects and porosity, Post-processing heat treatment, Applications in aerospace	**06**

Reference Books:

1. Kalpakjian, S., & Schmid, S. R. (2006). Manufacturing engineering and technology (5th SI ed.). Pearson Prentice Hall.
2. Groover, M. P. (2021). Fundamentals of modern manufacturing: Materials, processes, and systems (7th ed.). John Wiley & Sons.
3. Kou, S. (2003). Welding metallurgy (2nd ed.). Wiley-Interscience.
4. Gibson, I., Rosen, D. W., & Stucker, B. (2021). Additive manufacturing technologies (3rd ed.). Springer.
5. Courtney, T. H. (2000). Mechanical behavior of materials (2nd ed.). McGraw-Hill.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Tribology of Materials

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1	**MSE and TA**	30 and 20
Credit	3	**ESE**	50

Course Outcome:

At the end of course students will be able to:

1. Define different types of wear and wear modes in tribology.
2. Classify different wear measurement techniques to interpret material wear behavior.
3. Select suitable material combinations for improved tribological performance.
4. Analyze effect of material properties on wear rate of the materials.
5. Recommend suitable material system for desired operating window in tribology domain. 6. Modify tribological system for sustainable performance.
6. Analyse the material tribological system

Syllabus:

Unit	**Contents**	**Lecture**
01	**Fundamentals of Tribology:** Introduction to tribology, history of tribology, definitions and development of wear studies, factors influencing tribological phenomena, properties of materials relevant to friction and wear, scope and challenges; types of wear; relevant ASTM standards.	**06**
02	**Surfaces, Friction and Wear:** Contact of engineering surfaces: Hertzian and non-hertzian contact, contact pressure and deformation in non-conformal contacts, causes of friction, stick-slip friction behaviour and friction instability, sliding and rolling friction, frictional heating and temperature rise, wear and wear types, mechanisms of wear; wear map.	**06**
03	**Lubrication** Lubricants and their physical properties, types of additives, extreme pressure lubricants, recycling of used oils and oil conservation, oil emulsion, selection of lubricants, hydrodynamic lubrication: Reynolds equation, infinite bearing, short bearing, elastohydrodynamic lubrication: principle and application, pressure - viscosity term in Reynolds equation, Hertz theory, ErtelGrubin equation, Gas lubrication: Introduction, merits, demerits and applications, Lubrication in metal working: rolling, forging, drawing and extrusion.	**05**

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Unit	Contents	Lecture
04	**Surface Engineering for wear and corrosion resistance** Diffusion, coating, electro and electro-less plating, hot deep coating, metal spraying, cladded coating, crystallizing coating, selection of coating for wear and corrosion resistance, potential properties and parameters of coating.	06
05	**Wear monitoring, diagnosis and characterization techniques** Surface examination, vibration analysis, lubricant analysis, wear and friction measurement techniques, characterization of roughness and wear scar dimensions, microscopy techniques, 48 micromechanical properties techniques, thermal, chemical and x-ray methods	06
06	**Tribology of materials** Tribology of brass, cast iron and aluminium-silicon alloys, tribology of metal matrix composites, tribology of ceramic matrix composites, tribology of polymeric solids and their composites, tribology of diamond and diamond-like carbon films; Biotribology, Ocular tribology, nanotribology.	06

Textbooks:

1. Hutchings, I. M. Tribology: Friction and Wear of Engineering Materials. CRC Press, 1992.
2. Bhushan, B. Introduction to Tribology. John Wiley & Sons, 2nd Edition, 2013.

Reference Books:

1. Basic Lubrication Theory, A. Cameron, Ellis Hardwoods Ltd., UK. Engineering Tribology, J. A. Williams, Oxford Univ. Press.
2. Engineering Tribology, G. W. Stachowiak and A. W. Batchelor, Butterworth-Heinemann. Engineering Tribology, P. Sahoo, PHI, New Delhi.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Biomaterials

Course Code		Scheme of Evaluation	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	MSE and TA	30 and 20
Credits	3	ESE	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Analyze biological responses, cytotoxicity, and blood-material interactions.
2. Characterize and process biomaterials, including sterilization, and relate structure to performance.
3. Select and apply biomaterials for biomedical applications.

Syllabus:

Unit	Contents	Lecture
01	**Introduction to Biomaterials**: History and scope of biomaterials, Classification of biomaterials, Properties of biomaterials, Biofluids and medical devices, Biostructures, Biocompatibility, Hemocompatibility, and Degradation of biomaterials.	06
02	**Biomaterials-Types and processing:** Metallic biomaterials, ceramic-based biomaterials, polymer-based biomaterials, composite biomaterials, hydrogels, bioresorbable and bioerodible materials, natural biomaterials, nano biomaterials, pyrolytic carbon, thin films, grafts and coatings, Processing techniques and sterilization methods of biomaterials, Criteria for selection of biomaterials for specific applications.	06
03	**Biological response to biomaterials:** Host response to biomaterials, Inflammation and wound healing, foreign body response, Blood-material interactions, Hypersensitivity and systemic toxicity, Tumorigenesis, In-vitro and In-vivo evaluation of biomaterials, Cytotoxicity, cell adhesion and dissolution studies.	06

04	**Characterization and structure-property relationships of biomaterials:** Introduction to biomaterial characterization, Mechanical testing methods, Physical and Chemical characterization techniques, Surface characterization techniques, structure property relationships.	**06**
05	**Biomedical applications of biomaterials:** Orthopaedic applications, Dental applications, Cardiovascular applications, Ophthalmic applications, Sutures, Burn dressings, Drug delivery systems, Bioelectrodes, Biomedical sensors, and biosensors, Biomedical implants, Tissue engineering scaffolds.	**06**
06	**Modern biomaterials, Innovations, and Ethics:** Self-assembly of biomaterials for medical applications, Bio intelligent Implants, 4D bio fabrication, Biomimetic and smart biomaterials, Biomaterial-inspired design and innovations, Social, ethical, and regulatory issues and environmental considerations in biomaterials, Biomaterials market, standards for biomaterials and devices.	**06**

Textbooks:

1. V. Hasirci, N. Hasirci, Fundamentals of Biomaterials, Springer New York, New York, NY, 2018.
2. B.D. Ratner, ed., Biomaterials science: an introduction to materials in medicine, Academic Press, San Diego, 1996.

Reference Books:

1. A. Kumar, B. Basu, D. Katti, eds., Advanced biomaterials: fundamentals, processing, and applications, John Wiley & Sons, Hoboken, N.J, 2009.
2. J. Black, Biological Performance of Materials: Fundamentals of Biocompatibility, Fourth Edition, 4th ed, CRC Press, Hoboken, 2005.
3. J.B. Park, R.S. Lakes, Biomaterials: an introduction, 3rd ed, Springer, New York, 2007.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Advance materials for semiconductors and batteries

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Understand limitations of traditional silicon and justify the need for wide-bandgap semiconductors in advanced applications
2. Design and select appropriate semiconductor materials and 2D materials based on application requirements
3. Apply advanced fabrication techniques and operando diagnostics for materials development
4. Analyze electrochemical fundamentals and design high-performance electrocatalysts for energy conversion applications
5. Evaluate next-generation battery architectures and materials strategies to overcome conventional limitations
6. Assess environmental impact and sustainability of advanced semiconductor and battery technologies using lifecycle analysis

Syllabus:

Unit	Contents	Lecture
01	**Wide-Bandgap Semiconductors:** Limitations of traditional Silicon. Properties, crystal growth, and defect engineering of Silicon Carbide (SiC) and Gallium Nitride (GaN). Applications in power electronics, RF devices, and extreme environment operations. Comparative analysis: SiC vs GaN vs Si; Future WBG materials	**06**
02	**2D Materials and Transition Metal Dichalcogenides (TMDs):** Structure and electronic properties of TMDs like Molybdenum Disulfide (MoS2) and Tungsten Disulfide (WS2). Synthesis via Chemical Vapor Deposition (CVD). Integration into ultra-thin flexible electronics. Memristive devices and crossbar arrays for neuromorphic computing. Edge AI applications. Van der Waals heterostructures for device engineering. Challenges in scalability and reproducibility.	**06**
03	**Advanced Fabrication and Operando Diagnostics:** Wafer-scale processing, Plasma-Enhanced Chemical Vapor Deposition (PECVD), maskless lithography, and probe station testing. Cleanroom protocols. The rigorous "synthesis-characterize-test" workflow. Operando materials diagnostics to study real-time interface dynamics.	**06**

04	**Energy Conversion and Green Hydrogen:** Electrochemical fundamentals of energy conversion. Development of high current density electrocatalysts. Design and materials selection for alkaline electrolyzers and evaluation of Hydrogen Evolution Reaction (HER) performance. Scale-up challenges and cost analysis; Green hydrogen production pathways. Integration with renewable energy sources. Durability and corrosion resistance in alkaline environment.	**06**
05	**Next-Generation Battery Architectures:** Limitations of conventional Li-ion systems. Thermodynamics of Sodium-ion (Na-ion) and Lithium-Sulfur (Li-S) batteries. Transition to solid-state electrolytes (polymer, sulfide, oxide). The role of nanostructured materials in suppressing dendrites and enhancing cycle life. Multivalent ion batteries, Hybrid systems, Performance comparison of chemistries	**06**
06	**Sustainability and Lifecycle Analysis:** Degradation mechanisms in advanced semiconductors and batteries. Circular economy approaches for battery cathode recycling. Environmental impact of semiconductor fabrication workflows and strategies for sustainable, vendor-neutral processing. Regional considerations for India's semiconductor and battery ecosystem. Policy framework and incentives for green manufacturing.	**06**

Textbooks:

1. Sze, S. M., and Ng, K. K., Physics of Semiconductor Devices, 3rd Edition, John Wiley & Sons.
2. Huggins, R. A., Advanced Batteries: Materials Science Aspects, Springer.
3. Avouris, P., Heinz, T. F., & Low, T. (Eds.), 2D Materials: Properties and Devices, Cambridge University Press.

Reference Books:

1. Linden, D., & Reddy, T. B., Handbook of Batteries, McGraw-Hill.
2. Callister & Rethwisch, Materials Science and Engineering (10th Edition), Wiley, 2020
3. Michael Shur, Physics of Semiconductor Devices (2nd Edition), Prentice Hall, 2006
4. Masayoshi Arimatsu, Science and Technology of Advanced Lithium Batteries, Springer, 2019
5. A. Kumar & S. Goel, 2D Materials: Processing, Characterization, and Applications, Springer, 2016
6. P. Falagas & N. Baltas, Electrochemistry for Materials Engineering, Oxford University Press, 2020
7. C. Karunasena, Advanced Battery and Fuel Cell Technologies, Elsevier, 2020

Final Year B.Tech. Metallurgy and Materials Technology

Course: Mechanical Behaviour of Metals

Course Code		**Scheme of Evaluation**	MSE, TA, and ESE
Teaching Plan	3-0-0-1=3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Analyze mechanical deformation of the materials using analytical treatment.
2. Use mechanical metallurgical concepts in understanding mechanical deformation.
3. Identify failure modes and reasons of failures of engineering components.
4. Incorporate fracture mechanics concepts in the mechanical design.
5. Use micro structural principles for the design of fracture and creep resistant materials.

Syllabus:

Unit	**Contents**	**Le**
01	**Mechanical properties of materials, Theory of plasticity:** The flow curve, yielding criteria for ductile metals, Plastic deformation of single crystal and polycrystalline materials, Deformation by slips, Deformation by twinning, strain hardening of single crystals.	
02	**Dislocation theory:** Dislocations in FCC, HCP and BCC lattice, forces on dislocations, forces between dislocations, dislocation climb, intersection of dislocations, Jogs, multiplication of dislocations, dislocation pile-ups.	
03	**Strengthening mechanisms:** Strengthening of grain boundaries, yield point phenomenon, strain aging, solid solution strengthening, strengthening from fine particles, fiber strengthening, martensitic strengthening.	
04	**Fracture mechanics and fracture toughness evaluation:** Strain energy release rate, stress intensity factor, fracture toughness and design, KIC Plain-strain toughness testing, crack opening displacement, probabilistic aspects of fracture mechanics, toughness of materials.	
05	**Fatigue of metals:** Stress cycles, S-N curve, statistical nature of fatigue, low cycle fatigue, structural features of fatigue, fatigue crack propagation, effect of stress concentration on fatigue, size effect, surface effects and fatigue, effect of metallurgical variables on fatigue, corrosion fatigue, effect of temperature on fatigue.	

06	**Creep and Stress Rupture:** High temperature materials problem, time dependent mechanical behavior, creep curve, stress rupture, structural changes during creep, mechanisms of creep deformation, deformation mechanism maps, fracture at elevated temperature, high temperature alloys and Fractography-important aspects.	

Textbooks:

1. Mechanical behavior of materials, Courtney T. H., 2000. (2nd ed.). McGraw-Hill.
2. Mechanical Metallurgy – Geroge E. Dieter , SI Metric Edition ,1988, McGraw Hill.

Reference Books:

1. Mechanical Behaviour of Materials, Marc Andre Meyers and Kishan Kumar Chawala, Second Edition, 2009 , Cambridge University Press, U.K.
2. The Indian Academy of Sciences Proceedings : Engineering Science – Alloy Design , Vol 3 / Part 4, December 1980 and Vol 4 / Part 1, April 1981,Published by The Indian Academy of Sciences, Bangalore- 560080
3. Dislocations and Mechanical Behaviour of Materials, M.N. Shetty, 2013 , PHI Learning Pvt Ltd, New Delhi -110092.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Smart Materials

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Classify smart materials based on functionality and response mechanisms
2. Explain working principles of piezoelectric, shape memory, magnetostrictive, and electroactive materials
3. Analyze processing–microstructure–property relationships in smart materials
4. Compare advanced manufacturing routes for functional materials and devices
5. Apply additive manufacturing and digital manufacturing concepts to materials engineering problems
6. Propose smart manufacturing solutions using sensors, automation, and data-driven approaches

Syllabus:

Unit	Contents	Lecture
01	**Introduction to Smart Materials** Definition and characteristics of smart materials, Passive vs active smart materials, Multifunctional materials and adaptive systems, Evolution of smart materials and structures Application areas for smart materials: Aerospace, Biomedical , Robotics, Automotive, Electronics and MEMS.	**06**
02	**Functional Smart Materials** Piezoelectric Materials: Piezoelectric effect, Ferroelectric materials, Sensors and actuators, Applications in energy harvesting and vibration control Shape Memory Materials: Shape memory effect and superelasticity, Shape Memory Alloys (NiTi), Shape Memory Polymers Magnetostrictive and Electrostrictive Materials: Magnetostriction mechanisms, Giant magnetostrictive materials, Electroactive polymers Smart Composites: Fiber optic embedded composites, Self-healing materials, Adaptive composite structures, heat and cold resistant materials, radiation resistant materials,	**06**

03	**Processing and Characterization of Smart Materials** Processing of functional ceramics, Thin-film deposition techniques, Powder metallurgy routes, Polymer processing for smart polymers, Microfabrication and MEMS basics, Characterization methods: Electrical, Thermal, Mechanical and Functional characterization	**06**
04	**Additive Manufacturing and Advanced Manufacturing y** Fundamentals of additive manufacturing (AM), Methods for AM of metals, polymers, ceramics, and composites, 4D printing concepts, Smart structures fabricated by AM, Defects, residual stresses, and quality control	**06**
05	**Smart Manufacturing and Industry 4.0** Smart factories and cyber-physical systems, Sensors and data acquisition in manufacturing, Internet of Things (IoT) in manufacturing, Digital twins, AI and machine learning in materials manufacturing , Automation and robotics, Predictive maintenance, Sustainable and green manufacturing.	**06**
06	**Applications and Case Studies** Biomedical implants and wearable devices, filters for water cleaning, biodegradable packages Structural health monitoring systems, Smart coatings and corrosion monitoring, Energy harvesting devices, Flexible electronics and soft robotics, Case studies from aerospace and automotive industries	**06**

Textbooks:

1. *M. V. Gandhi and B. S. Thompson, Smart Materials and Structures. London, U.K.: Chapman & Hall, 1992*.
2. D. Bourell, J.-P. Kruth, M. Leu, G. Levy, D. Rosen, A. M. Beese, and A. Clare, "Materials for additive manufacturing," *CIRP Annals*, 2017
3. B. Culshaw, *Smart Structures and Materials*. Boston, MA, USA: Artech House, 1996.
4. I. Gibson, D. W. Rosen, and B. Stucker, *Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing*, 2nd ed. New York, NY, USA: Springer, 2015

Reference Books

1. A. V. Srinivasan and D. M. McFarland, *Smart Structures: Analysis and Design*. Cambridge, U.K.: Cambridge University Press, 2001.
2. Design, Fabrication Properties and Applications of Smart and Advanced Materials, Edited by Xu Hou, CRC Press, 1st Edition, 2016
3. V. Vijayan, R. P. Shetty, and S. P. Pai, Eds., *Smart Materials and Manufacturing Technologies for Sustainable Development*. Cham, Switzerland: Springer Nature, 2024.
4. C. K. Chua and K. F. Leong, *3D Printing and Additive Manufacturing: Principles and*

Applications, 5th ed. Singapore: World Scientific Publishing, 2017.

Software / Tools Exposure (Recommended)

- ANSYS / COMSOL for smart material simulations
- SolidWorks / Fusion 360 for design
- MATLAB/Python for data analysis
- CES EduPack / Granta Selector
- Basic IoT platforms (Arduino/Raspberry Pi)

Final Year B.Tech. Metallurgy and Materials Technology

Course: Light Metals and Alloys

Course Code		Scheme of Evaluation	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Understand extraction of light metals.
2. Explain solidification processes, thermodynamics involved and physical metallurgy of light alloys.
3. Compare processing routes used for manufacturing light alloys.
4. Depict structure-property relationship of various light metal alloys and select these alloys for real-world applications.
5. Design new alloy systems or processing route or heat treatment for light metals and alloys.

Syllabus:

Unit	Contents	Lecture
01	**Introduction:** Definition, Characteristics, production of aluminium, production of magnesium, production of titanium, usage and economics, recent trends	**06**
02	**Thermodynamics and kinetics of solidification:** homogeneous and heterogeneous nucleation, dendritic growth, solid/liquid Interface stability, Heat flow, heat evolution, shrinkage, macro and micro segregation, Recent advances in processing: Semi solid processing (SSP), Thixographic processing	**06**
03	**Aluminium Alloys: Wrought Al Alloys:** Designation and Tempers heat treatable and non-heat treatable alloys, Li containing alloys, joining. **Special products**- aircraft alloys, automotive alloys, packaging alloys, electrical conductor alloys, **Cast Aluminium Alloys:** Designations, tempers and characteristics, alloys based on Al-Si, Al-Cu, Al-Mg, Al-Zn-Mg systems, modification in Al-Si alloys, joining	**06**

04	**Physical Metallurgy of Al Alloys:** Work hardening and annealing, forming limit curves, textures, principles of age hardening, microalloying effects, hardening mechanisms, aging processes, mechanical behaviour, corrosion behaviour	**06**
05	**Magnesium Alloys:** Introduction to alloying behaviour, alloy designations, Zr-free and Zr-containing alloys, wrought magnesium alloys, extrusion alloys, forging alloys, trends in applications of Mg alloys, electrochemical aspects	**06**
06	**Titanium Alloys:** Introduction and classification, basic principles of heat treatments, wrought and cast commercial titanium alloys, texture effects, surface treatments, engineering performance- tensile, creep, and fatigue behaviour, Applications- general application of Titanium Alloys, aerospace, power generation, automotive, marine, biomaterials	**06**

Text Books:

1. Polmear I.J., Light Alloys, 4th Ed., Butterwort Heinemann 2006

Reference Books:

1. Brandes E.A. and Brook G.B., Smithells Light MetalsHandbook, Elsevier 1998
2. Totten G.E. and Mackenzie D.S., Handbook of Aluminum Vol.1: Physical Metallurgy and Processes, CRCPress 2003
3. Friedrich H.E., Mordike B.L. and Friedrich H., Magnesium Technology, 1st Ed. Springer 2004 ,
4. Ber L.B., Kolobnev N. and Kablov E.N., Heat Treatment of Aluminum Alloys: Advances in Metallic Alloys, CRC Press,2010
5. Lütjering G., Williams J.C., Titanium, 2nd edition, Springer,2007

Final Year B.Tech. Metallurgy and Materials Technology

Course: Electronic and Magnetic Materials

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Identify and explain the basic principles of various electronic and magnetic materials.
2. Apply various laws and relations to evaluate the suitability of various electronic and magnetic materials for a particular application.
3. Analyze the effect of process parameters on the structure - property relationship of electrical engineering materials.
4. Engineer the synthesis-structure property relationship for the electronic materials according to recent commercial applications.

Syllabus:

Unit	Contents	Lecture
01	**Electrical Materials** Electrical and Thermal Conduction In Solid metal and conduction by electrons, Resistivity and its Temperature dependence, Thermal Conductivity, Thermal Resistance Temperature coefficient of Resistivity, Impurity Effect, Resistivity Mixture Rule, Skin Effect. Electrical Conductivity of Non -Metals: Ionic Crystals and Glasses, Semiconductors, Solar Radiation Fundamentals	**06**
02	**Semi -conductor Materials** Semiconductors, Extrinsic, Intrinsic, Recombination and Generation in Semiconductors, Semiconductor Devices, Compound Semiconductor, Metal Semiconductor contacts, Microelectronic Devices Such as LED, CMOS, MOSFETS, BPT etc, Manufacturing Methods and Applications, Si wafer Manufacturing, Solar Cell Device and Quantum Efficiency Calculations	**08**
03	**Magnetic Properties:** Magnetic Field and Quantities, Classification of Magnetic Materials, Ferromagnetism Origin, Exchange Interaction, Saturation Magnetization, Curie Temperature, Ferromagnetic Domains, Magnetostriction,	**08**

	Demagnetization	
04	**Magnetic Alloys:** Soft and Hard Magnetic materials, Ferrites, Magnetic Recording Materials, Magnetic Resonance Imaging. Superconductivity: Zero Resistance, Meissner Effect, Type I and II Superconductors, BCS Theory, Magnetoelectric materials, Multiferroicity.	**08**
05	**Optical Properties of Materials:** Light and Electromagnetic Spectrum, Refraction, Absorption, Transmission and Reflection of Light, Luminescence, Laser, Optical Spectral bands, Basic optical laws and definitions, Optical fibers Modes and configurations, Fiber materials and fabrication, Optical Anisotropy, Electrooptic Effect, Electro-optic Ceramics, Antireflection Coating on Solar Cell.	**06**
06	**Dielectric Materials and Insulation:** Polarization, Relative Permitivity, Polarization Mechanisms, Dielectric Constant, Dielectric Loss, Capacitors and Insulators, Piezoelectric, Ferro Electric and Pyroelectric Materials, Supercapacitors.	**06**

Textbooks:

1. William F. Smith , Javed Hashemi, Ravi Prakash, " Foundation of Materials Science and Engineering", TATA Mc Graw-Hill International Edition,4th Edition, 2008.
2. N. Braithwaite and G. Weaver," Materials in Action Series -Electronic Materials", Butterworths Publication.
3. S. O. Kasap," Principles of Electronic Materials and Devices", Tata Mc Graw-Hill Publication, 2nd Edition, 2002.
4. Robert Pierret, "Advanced Semiconductor Fundamentals", Vol.6 (Modular Series on Solid State Devices, Vol 6), 1987, Pearson Publications.
5. S. M. Sze, Physics of Semiconductor Devices, 2006, Wiley Publication.

Reference Books:

1. Schroder, Klaus, "Electronic Magnetic and Thermal properties of Solids", Marcel Dekker, New York 1978.
2. Electronic Materials Handbook, ASM International, Materials Park, 1989.
3. Buschow K.H.J.," Handbook of Magnetic Materials", Amsterdam: Elsevier, Volume 15, First Edition December 2003.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Sustainable Processes

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcomes (COs):

At the end of the course, students will demonstrate the ability to:

1. Understand the environmental and energy-related challenges in conventional metallurgical processes.
2. Evaluate strategies for minimizing waste, emissions, and energy usage in metallurgy.
3. Apply principles of circular economy and life cycle assessment to metallurgical processes.
4. Compare sustainable practices in ferrous, non-ferrous, and secondary metal industries.
5. Evaluate techno commercial viability, mass and energy balance of processes.
6. Design processes for sustainability and green manufacturing.

Syllabus

Unit	Contents	Lectures
01	**Foundations of sustainable metallurgy:** UN Sustainable Development Goals (SDGs); Need of sustainability in metallurgy; environmental impacts of metallurgical industries; circular economy and industrial ecology; Life Cycle Assessment (LCA); Environmental Impact Assessment (EIA); overview of carbon/ ecological footprint and ESG metrics; ISO 14001, REACH, CPCB norms.	**06**
02	**Sustainable mining and mineral processing**: Environmental impacts of mining; sustainable mine planning and reclamation; green mining technologies; sustainable crushing and grinding; water-efficient mineral processing; tailings management and waste valorisation; bio-mining and microbial leaching; mass and energy balance in beneficiation systems.	**06**
03	**Green extraction metallurgy and decarbonization technologies:** Sustainable iron and steelmaking; hydrogen metallurgy and H_2-DRI; green aluminium and copper extraction; electro-metallurgical systems; renewable energy integration; carbon capture and utilization (CCUS); waste heat recovery systems; water treatment and zero-liquid discharge systems.	**06**

04	**Sustainable metal working and green alloy design** : Sustainable rolling, forging, extrusion and wire drawing; sheet metal forming sustainability; tribology and wear-related pollution; air pollution and emission control, tire and brake wear particulate pollution; sustainable lubrication systems; eco-friendly coatings; design for recyclability; lightweight alloys; biomimetic and nature-inspired materials.	06
05	**Sustainable manufacturing and circular metallurgy**: Green manufacturing principles; sustainable casting and foundry practices; additive manufacturing and sustainability; sustainable machining and MQL; recycling of steel, aluminium, copper and batteries; urban mining and e-waste recycling; industrial symbiosis and waste valorisation; circular economy assessment.	06
06	**Industrial case studies and design of sustainable processes:** Green steel technologies; net-zero metallurgical plants; hydrogen economy and metallurgy; smart manufacturing and Industry 5.0; digital twins and AI in metallurgy; renewable-energy-driven metallurgical plants; comparative LCA studies	06

Textbooks:

1. Birat, Jean-Pierre. "Sustainable Materials Science-Environmental Metallurgy: Volume 1: Origins, basics, resource and energy needs." *Sustainable Materials Science-Environmental Metallurgy*. EDP sciences, 2020.
2. Birat, Jean-Pierre. "Sustainable Materials Science-Environmental Metallurgy: Volume 2: Pollution and emissions, biodiversity, toxicology and ecotoxicology, economics and social roles, foresight." *Sustainable Materials Science-Environmental Metallurgy*. EDP sciences, 2021.

Reference Books:

1. Sustainable Materials - With Both Eyes Open by Julian Allwood et al.
2. Stroud, Dean, et al. *Industry 4.0 and the road to sustainable steelmaking in Europe: Recasting the future*. Springer Nature, 2024.
3. Innovations in Mini Blast Furnaces: Toward Sustainable Metallurgy by Aitber Bizhanov, Pruet Kowitwarangkul, Sergey Gavrilovich Murat, Alexander Rostovskiy, Suporn Kittivinitchnun, Springer, 2025.
4. Sustainable Metals Management: Securing Our Future - Steps Towards a Closed Loop Economy: 19 (Eco-Efficiency in Industry and Science), by Arnim von Gleich (Editor), Robert U. Ayres (Editor), Stefan Gößling-Reisemann (Editor), Springer-Verlag New York Inc.; 2006.
5. Botin, J. A., ed. *Sustainable management of mining operations*. SME, 2009.
6. Selected journal articles from the journal of sustainable metallurgy, resources, conservation and recycling, etc.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Crystallographic Texture in Materials

Course Code		Scheme of Evaluation	MSE, TA, and ESE
Teaching Plan	3-0-0-1=3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of this course, the students will demonstrate the ability to:

1. Understand the fundamentals of crystallographic texture and its representation.
2. Explain texture formation during various metal processing methods.
3. Analyze the effects of texture on anisotropy in materials properties.
4. Apply texture characterization techniques like XRD and EBSD

Syllabus:

Unit	Contents	Lecture
01	Concepts of texture in materials, their representation by pole figure and orientation distribution functions. ODF to Pole Figure Conversion. Macro and Micro Texture measurement by X-ray diffraction, EBSD.	**08**
02	Origin and development of textures during materials processing stages: solidification.	**04**
03	Deformation, annealing, phase transformation. Deformation microstructure and texture in FCC, BCC and HCP metals and alloys. Texture evolution during annealing.	**08**
04	Influence of texture on mechanical, chemical and physical properties: Yield strength, ductility, fatigue, corrosion, stress corrosion cracking, magnetic and dielectric properties.	**06**
05	Introduction to Grain boundaries in polycrystalline materials: LAGB, HAGB, cell/subgrain structure.	**04**
06	Role of grain boundary character on interface-controlled properties (segregation, creep, fracture, sensitization). Concept of grain boundary engineering. Case studies.	**06**

Textbooks:

1. S. Suwas, and R. K. Ray, Crystallographic Texture of Materials, Springer-Verlag

Reference Books:

1. M. Hatherly and W. B. Hutchinson, An Introduction to Texture in Metals (Monograph No. 5), The Institute of Metals, London.
2. V. Randle, and O. Engler, Introduction to Texture Analysis: Macrotexture, Microtexture and Orientation mapping, Gordon and Breach Science Publishers.

3. F. J. Humphreys, and M. Hatherly, Recrystallization and Related Phenomenon, Pergamon Press
4. P. E. J. Flewitt, and R. K. Wild, Grain Boundaries

Course: High Entropy Alloys

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcomes:

1. Explain the fundamental concepts, classification, and core effects associated with high entropy alloys.
2. Apply thermodynamic and phase stability principles for designing HEAs using empirical and computational approaches.
3. Analyse the influence of processing routes on microstructure evolution in high entropy alloys.
4. Correlate microstructure with mechanical, tribological, thermal, oxidation, and corrosion properties of HEAs.
5. Evaluate advanced applications, sustainability aspects, and future research opportunities in high entropy and compositionally complex alloys.
6. Design and fabrication of HEA alloys from application point of view.

Syllabus:

Unit	Contents	Lectures
01	**Introduction to high entropy alloys:** Historical evolution of alloy design philosophy: conventional alloys to multi-principal element alloys; concept and definition of High Entropy Alloys (HEAs), Medium Entropy Alloys (MEAs), and Compositionally Complex Alloys (CCAs); Core effects of HEAs: high entropy effect, sluggish diffusion, severe lattice distortion, cocktail effect; classification of HEAs based on crystal structure and application; comparison with traditional alloys and superalloys.	**06**
02	**Thermodynamics of high entropy alloys:** Physical metallurgy of high entropy alloys, configurational entropy and Gibbs free energy; diffusion behaviour, compositional effect, processing conditions, deformation behaviour, Thermodynamic principles governing HEAs, entropy of mixing, enthalpy of mixing, atomic size difference, valence electron concentration, electronegativity difference; solid solution formation criteria, Hume-Rothery rule, phase stability in HEAs; Comparison with bulk metallic glass formation	**06**

03	**Principles of alloy design for high entropy alloys:** Predictive approaches for phase stability, CALPHAD approach and computational thermodynamics, Ab-initio calculations, molecular dynamics simulation, Monte carlo simulations, empirical parameters for alloy selection; binary and multicomponent phase diagrams relevant to HEAs; phase-field modelling, machine learning and ICME approaches in alloy design.	06
04	**Synthesis, processing and microstructure evolution:** Processing routes for HEAs: Liquid metallurgy route, additive manufacturing, solid state processing; carbothermal shock synthesis, combinatorial approaches, vacuum arc melting, induction melting, powder metallurgy, spark plasma sintering, additive manufacturing, mechanical alloying, thin film deposition techniques; solidification behaviour; casting defects and homogenization; grain structure evolution; phase transformations in HEAs; precipitation behaviour; nano-structured and eutectic HEAs; Microstructures of solid solution phases in HEAs, influence of heat treatment and thermomechanical processing on microstructure.	06
05	**Structural and functional properties of HEA:** Mechanical behaviour of HEAs: tensile properties, hardness, ductility, fracture toughness, fatigue, creep, wear resistance; strengthening mechanisms in HEAs; deformation mechanisms including dislocation slip, twinning, TRIP and TWIP effects; high-temperature properties; cryogenic behaviour of HEAs; irradiation resistance; magnetic, electrical, thermal and electrochemical properties of HEAs. Corrosion behaviour of HEAs in aqueous and aggressive environments; passivation mechanisms; oxidation resistance at elevated temperatures; hot corrosion; tribo-corrosion behaviour; coatings and surface engineering of HEAs; environmentally assisted degradation;	06
06	**Advanced HEAs and emerging applications:** Refractory HEAs; lightweight HEAs; eutectic HEAs; Transition metal HEAs, noble metal HEAs, amorphous and nano-crystalline HEAs; Intermetallic compounds : B2 phase, sigma phase, L12 phase, Laves phase, Hagg phase; HEA thin film coatings vs conventional hard coatings, high entropy thick film coating, HEA composites; HEA ceramics, biomedical HEAs; HEAs for hydrogen economy, nuclear, aerospace, defence, marine and energy applications; current research trends; industrial challenges and commercialization prospects; future directions in HEA research, sustainability and recyclability considerations in HEA development; life-cycle assessment concepts.	06

Textbooks

1. Murty, B. S., Yeh, J. W., Ranganathan, S., & Bhattacharjee, P. P. (2019). *High-entropy alloys*. Elsevier.

2. Gao, M. C., Yeh, J. W., Liaw, P. K., & Zhang, Y. (Eds.). (2016). *High-entropy alloys: fundamentals and applications*. Springer.

Reference Books

1. Rajendrachari, S. (Ed.). (2025). Handbook of High Entropy Alloys: Fundamentals to Applications. CRC Press.
2. Srivatsan, T. S., & Gupta, M. (Eds.). (2020). High entropy alloys: innovations, advances, and applications.
3. Zhang, Y., & Li, R. (2020). New advances in high-entropy alloys. *Entropy*, *22*(10), 1158.
4. Additional learning resources as recommended by the course teacher.

Final Year B.Tech. Metallurgy and Materials Technology

Course: Design & Selection of Materials

Course Code		**Scheme of Evaluation**	MSE, TA and ESE
Teaching Plan	3-0-0-1 = 3	**MSE and TA**	30 and 20
Credits	3	**ESE**	50

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Explain the role of materials in engineering design.
2. Analyze material properties relevant to component performance.
3. Use material selection charts and indices for optimal selection.
4. Select materials considering manufacturing, cost, and environmental factors.
5. Solve real-life design problems through case studies and projects such as design and manufacture different machines and structures for industrial applications.
6. Gain knowledge regarding the scientific methodology with a multidisciplinary approach.

Syllabus:

Unit	Contents	Lecture
01	**Introduction to Materials in Design** Evolution of engineering materials, Design process and design methodology, Types of engineering design, Design flow chart- tools and material data, Functional requirements and constraints, Interaction between: Function, Material, Shape and Manufacturing process; Overview of engineering materials: Metals and alloys, Ceramics, Polymers, Composites, special materials: Ti –alloys, Graphene, superalloys, stainless steels for nuclear application, Relative costs and alternative materials.	**06**
02	**Material Properties for Design** Mechanical properties and their interrelationship: Strength, Elastic modulus, Toughness, Hardness, Fatigue, Creep, Wear, Deep drawing ability, fracture toughness, Thermal properties (ceramic & refractory tests - spalling, softening temperature, pyrometric cone equivalent, porosity etc.), Electrical and magnetic properties, Corrosion and wear resistance, Property-performance relationships, Materials property databases and standards applicable all tests (ASTM, DIN etc.).	**06**
03	**Materials Selection Methodology-I** Systematic material selection procedure, translation of design	**06**

	requirements, Ashby approach to materials selection, Material indices, method of finding indices, Performance indices for: Stiffness-limited design, Strength-limited design, Lightweight design, Ashby material selection charts: Modulus-density, Strength-density, Fracture toughness-strength.	
04	**Materials Selection Methodology-II** Multiple constraints and objectives, conflicting objectives, penalty-functions, exchange constants; Materials Substitution, Pugh Method, concurrent engineering design, Use of software/tools (CES EduPack/Granta Selector overview).	**06**
05	**Manufacturing, Economics and Sustainability** Manufacturing process selection, Process-property relationships, Cost analysis in material selection, Availability and standardization, Reliability and safety considerations, Sustainable materials selection, Eco-design and life cycle analysis (LCA), Recycling and environmental impact. concept of material – process compatibility - examples.	**06**
06	**Applications and Case Studies** Materials selection for: Aerospace applications, Automotive components, Biomedical implants, High-temperature applications, Corrosion-resistant systems, Electrical/electronic devices, Failure analysis in design, Industrial case studies, Use of Industry 4.0.	**06**

Text Books:

1. Michael F. Ashby, "Materials Selection in Mechanical Design", Fifth edition, Elsevier, 2016
2. J. Charles, F.A.A. Crane, J. A.G. Furness, "Selection and Use of Engineering, Materials", third edition, Butterworth-Heinemann, 2006

Reference Books:

1. ASM Metals Handbook, Materials Selection and Design, Vol. 20,2010
2. Myer Kutz, "Handbook of Materials Selection", John Wiley & Sons, Inc., New York, 2002, ISBN 0-471-35924-6

Final Year B.Tech. Metallurgy and Materials Technology

Course: Internship

Course Code		**Scheme of Evaluation**	CIE
Teaching Plan	0-0-6-0 = 3	**ESE**	100
Credits	3		

Course Outcome:

At the end of the course, students will demonstrate the ability to:

1. Apply metallurgical and materials engineering knowledge for the development of innovative solutions, product improvement, prototyping, or process optimization.
2. Transform proof-of-concept ideas from Project Stage-III into scalable models, industrial applications, or start-up-oriented solutions.
3. Acquire and demonstrate proficiency in modern engineering tools, research methodologies, and industrial practices relevant to advanced materials and manufacturing sectors.
4. Apply critical thinking, experimentation, and data interpretation techniques to analyse and solve complex industrial or research problems.
5. Exhibit professional ethics, effective communication skills, teamwork, leadership qualities, and adaptability in industrial, research, or international work environments.
6. Prepare and present comprehensive technical reports, project documentation, and presentations demonstrating the outcomes, innovations, and learning achieved during the internship.

Nature of Internship

Industry / R and D labs / Education institutes (HEI less than 100 NIRF rank)

Scope of internship

The project student group can pursue innovation (TRL > 4) on carry forward ideas / Proof of concept derived from Project Stage-III for scaling up the model/prototyping/product development / Start-up.

"OR"

Students can pursue international internship abroad / Preplacement / Internship in Industry / Education institutes (less than 100 NIRF) / R and D labs

Final Year B.Tech. Metallurgy and Materials Technology

Scheme Name	Course Scheme		Evaluation
A[*]	In campus		Report and Presentation
B[#]	Off Campus	Industry	Report and Presentation
		Educational Institute	Report and Presentation
		R&D Lab	Report and Presentation
C[$]	International Internship		Report and Presentation

[*] If students are undertaking scheme A, then they are required to opt for department Curriculum.

[#] If students are undertaking scheme B, then they are required to opt for MOOCs courses as approved by the department.

[$] If students are undertaking scheme C, then they are required to opt for MOOCs courses as approved by the department or in accordance to rules/regulations of the respective international university/industry/R&D labs for credit transfer; in such a case a prior approval of equivalent credits have to be obtained from Dean/Director (Exam).