Jharkhand University of Technology

Ranchi

Master of Technology

SPECIALIZATION –PHYSICAL METALLURGY

Course Structure & Syllabus

SYLLABUS FOR

CREDIT BASED CURRICULUM

2021 – 22

ON WARDS

Department of Metallurgical Engineering

December 2021

(With effect from Academic Year 2021-22)

Course Structure M. Tech. (Specialization –Physical Metallurgy)
Academic Session 2020-21 onwards

SEMESTER I

S. No.	Course Code	Course	Subject	L	T	P	Cr.
1.	PM 1101	Core - I	Metallurgical Thermodynamics and Kinetics	3	0	-	3
2.	PM 1102	Core - II	Solidification of Metals and Alloys	3	0	-	3
3.	PM 1103 PM 1104 PM 1105 PM 1106	Programme Elective - I	1 Fatigue and Fracture Mechanics 2 Physical Metallurgy of Advance Metallic Materials 3 Structure and Properties of Materials 4 Powder Production and Processing	3	0	-	3
4.	PM 1107 PM 1108 PM 1109 PM 1110	Programme Elective - II	1Mechanical Behaviour of Materials 2 Alloy Steels Technology 3 Nanostructured Materials 4 Advanced Materials Engineering	3	0	-	3
5.	PM 1111 PM 1112 PM 1113 PM 1114	Programme Elective - III	1.Physical Metallurgy of Alloy Steels 2. Joining of Materials 3. Computational Methods for Metallurgy 4 Advanced Foundry Technology	3	0	-	3
6.	PM 1201	Lab - I	Metallurgical Thermodynamics and Kinetics laboratory	-	-	3	2
7.	PM 1202	Lab - II	Heat Treatment of metals & Alloy Steels Laboratory	-	-	3	2
8.	**RMC1101**	Compulsory Paper	Research Methodology & IPR	2	-	-	2
9.	**A10001** **A10002** **A10003** **A10004**	**Audit I**	English for research paper writing Professional ethics Constitution of India Stress management by yoga	2	-	-	0
	Total Credits						**21**

METALLURGICAL ENGINEERING DEPARTMENT
Course Structure M. Tech. (Specialization - Physical Metallurgy)

Academic Session 2020-21 onwards
SEMESTER II

S. No.	Course Code	Course	Subject	L	T	P	Cr.
1.	PM 2101	Core - III	Phase Transformation in Materials	3	0	-	3
2.	PM 2102	Core - IV	Characterization of Materials	3	0	-	3
3.	PM 2103 PM 2104 PM 2105	Programme Elective - IV	1. Composite Materials 2. Polymer Engineering 3 Corrosion and Protection of Materials	3	0	-	3
4.	PM 2106 PM 2107 PM 2108 PM 2109	Programme Elective - V	1. X-Ray and Electron Microscopy 2. Mechanical Working of Materials 3. Functional Materials 4 Advances in Non-Ferrous Technology	3	0	-	3
5.	PM 2110 PM 2111 PM 2112 PM 2113 PM 2114 PM 2115	Open Elective - I	1.BusinessAnalytics 2.IndustrialSafety 3.OperationsResearch 4.CostManagementof Engineering Projects 5.Composite Materials 6.Waste to Energy	3	0	-	3
6.	PM 2201	Lab - III	Metallography laboratory	-	-	3	2
7.	PM 2202	Lab - IV	Materials Characterization laboratory	-	-	3	2
8.	PM 2203	Lab	Mini Project	-	-	3	2
9.	**A20001**	Audit II	Disaster management	2	-	-	0
	A20002		Value education				
	A20003		Soft skills				
	A20004		Personality development through life enlightenment skills				
	Total Credits						**21**

SEMESTER- III			
S. No	**Course Code**	**Course/ Subject**	**Credits**
01.	PM3201	DISSERTATION Phase- I	10
Total Credits			**10**

SEMESTER- IV			
S. No	**Course Code**	**Course/ Subject**	**Credits**
01.	PM4201	DISSERTATION Phase- II	16
Total Credits			**16**

SEMESTER I
Core I: Metallurgical Thermodynamics and Kinetics (PM 1101)

Course Objectives: Student should be able to:
(i) To understand fundamental laws of thermodynamics

(ii) To be able to apply thermodynamics in understanding allotropic and phase changes in the metal and alloys

(iii)To competent to predict feasibility of various chemical reactions associated with synthesis of alloys and composites and also comment on structural changes in alloys based on nucleation, and kinetics.

Syllabus Content:
Module 1 : Laws of thermodynamics and their applications; Enthalpy; Entropy associated with different processes; Gibbs and Helmholtz free energy; Criteria of equilibrium; Concepts of activity, fugacity and standard states;
Module 2 : Ellingham diagram; Free energy – composition diagram; Solutions – Raoult's and Henry's Laws; Ideal, real and regular solutions; Gibbs – Duhem equation. ; Activation energy and its applications;
Module 3 : Homogeneous and heterogeneous reactions; Factors affecting the heterogeneous reactions kinetics in solid – solid, solid – gas and solid – liquid systems; Rate controlling steps; Kinetic model equations,
Module 4 : Fick's laws of diffusions and their applications in metallurgy;
Module 5 : Slag – metal reaction kinetics ; Concept of boundary layer and its impact on reaction kinetics.

Course outcomes: Upon completion of the course, the student will be able to:
1. Understand the basic laws of thermodynamics.

2. Understand the multiple approaches to thermodynamics, from the bulk property point of view and from the atomistic point of view .

3. Understand concepts such as the theory of solutions, free energy, entropy, criteria for equilibrium and conditions for feasibility.

4. Obtain the skill to use metallurgical thermodynamic concepts and equations for understanding phase diagrams, phase transformations, theory of solutions .

Essential Readings:
1. D.R.Gaskell, Introduction to Metallurgical Thermodynamics, McGraw Hill, New York, 1973.
2. G.S.Upadhyay and R.K.Dubey, Problems in Metallurgical Thermodynamics and Kinetics, Pergamon, New York, 1977.
3. J.Szekely and N.J.Themelis, Rate Phenomena in Process Metallurgy, John Wiley, New York.
Supplementary Readings:
1. A.K.Mohanty, Rate Processes in Extractive Metallurgy, Prentice Hall of India.

Core II : Solidification of Metals and Alloys (PM 1102)

Course objective: To study the phase changes that occurs during both thermal and thermo mechanical treatments.

Syllabus Content:

Module 1 : Phase rule and phase diagram, Allotropy of Iron and Fe-C Phase diagram, Nucleation and growth kinetics, Atomic models of Diffusion, Steel, Functions of alloying elements in steel, Importance of Austenite Grain size.

Module 2 : Formation of Austenite, TTT and CCT Diagrams, Pearlitic, Bainitic and Martensitic Transformations (Mechanisms, Kinetics and Morphologies). Pearlitic transformation, Factors influencing pearlitic transformation, Mechanism of transformation, Nucleation and growth, Orientation relationship.

Module 3 : Bainitic transformation: Mechanism of transformation, Nucleation and growth, Orientation relationships, Surface relief, Classical and non-classical morphology, Effect of alloying elements.

Module 4 : Martensitic transformation: Characteristics of transformation, Thermodynamics and kinetics, Nucleation and growth, Morphology, Crystallography, Stabilization.

Module 5 : Heat treatment of steels: annealing, normalizing, hardening, tempering, austempering, patenting, industrial practices Strengthening mechanisms, Recovery, Recrystallization and Grain growth

Course outcomes: Upon completion of the course, the student will be able to:

1. Analyse the Phase diagram and Microstructure using Microscope for different type of metals and alloys steel.
2. Understand the heat treatment of steels using TTT and CCT.
3. Determine the heat treatment conditions required to obtain a given microstructure using TTT diagrams.

Essential Reading:

1. R. E. Reed-Hill, Physical Metallurgy Principles, East-West Press.
2. V. Raghavan, Solid State Phase Transformations, PHI.

Supplementary Reading:

1. J. W. Christian, The Theory of Transformations in Metals and Alloys, Pergamon Press.
2. D. A. Porter and K E Easterling,Phase Transformations in Metals and Alloys, CRC Press.
3. J. E. Hilliard, Phase Transformations, ASM.
4. S. H. Avner, Introduction to Physical Metallurgy, Tata MeGraw-Hill.
5. R. E. Reed-Hill, Physical Metallurgy Principles, East-West Press.
6. A. K. Jena and M. C. Chaturvedi, Phase Transformation in Materials, Prentice Hall

Program Elective I : Fatigue and Fracture Mechanics
(PM 1103)

Course objective: To develop the knowledge about the essential mechanical properties of engineering materials such as fatigue and fracture and to apply them to design the materials for various load-bearing structural engineering applications.

Syllabus Content:
Module 1 : Introduction: Deformation and fracture.Ductile and brittle fracture.Griffith theory of brittle fracture and its modifications.
Module 2 : Linear elastic and elastic-plastic fracture mechanics: Stress intensity parameter, J integral and crack tip opening displacement as fracture criteria, standard procedures for experimental determination of these parameters. Correlation of fracture toughness with other mechanical properties and microstructure.
Module 3 : Fatigue: Principles of fatigue. Sub-critical crack growth under fatigue. Stress and crack length correlations with fatigue crack propagation, fatigue life calculations, crack initiation and propagation mechanisms, ΔK_{Th}, short crack growth behaviour, crack closure, effects of overloads and variable-amplitude loading, micro structural aspects.
Module 4 : Environment assisted cracking: sub-critical crack growth under static loading, critical stress intensity factor (K_{IEAC}), crack growth mechanisms, major variables affecting crack growth, life prediction. Stress corrosion cracking, hydrogen embrittlement and liquid metal embrittlement. Corrosion fatigue, true corrosion fatigue and stress corrosion fatigue.
Module 5 : Applications of fracture mechanics: Failure analysis, 'Fail-safe' and 'Safe-life' design and 'Leak-before-break' design concepts.

Course outcomes: At the end of this course, the students would be able to:
1. Define the life assessment of various engineering materials and associated testing methods .

2. Describe basic mechanisms of fatigue behavior of various engineering materials and their importance in materials design.

3. Analyze the various metallurgical factors influencing the fatigue performance of materials for different structural engineering applications.

4. Provide suitable remedial measure to prevent premature failure and reduction in performance .

5. Describe the failure modes and root cause of the materials failure based on fracture mechanics and fractography approach.

READINGS AND TEXTBOOKS:

1. RW Herzberg: Deformation and Fracture Mechanics of Engineering Materials, Fourth Edition, John Wiley & Sons INC, USA
2. GE Dieter: Mechanical Metallurgy, SI Metric Edition, McGraw-Hill Inc,, UK

REFERENCE BOOKS :

1. S.Suresh, Fatigue of Materials, Second Edition, Cambridge University Press, UK, 1998.
2. Fatigue, Fracture and Integrity Assessment (FFIA 2007), eds. M. Shome and D. Bhattacharya, Tata Steel Limited, Jamshedpur, 2007, India.
3. Fatigue and Fracture: ASM Handbook, ASM International,1996.
4. S. Kocanda : Fatigue Failure of Metals, Sijthoff&Noordhoff International Publishers, Poland, 1978.

Program Elective I : Physical Metallurgy of Advance Metallic Materials (PM 1104)

Course objective: To develop an understanding of the basic principles of physical metallurgy in metallic materials and apply those principles to engineering applications.

Syllabus Content:

Module 1 : Special steel: High strength low alloy (HSLA) steel, Dual phase steel, Duplex stainless steel, TRIP steel, Maraging steel, High speed steel, Stainless steel: ferritic, austenitic and martensitic. Precipitation & dispersion hardenable materials,

Module 2 : Age hardenable alloys: Al-Cu alloys, Al-Fe-V-Si alloys. Super alloys: Ni, Fe and Co based super alloys, Ti based alloys & their thermomechanical treatment, Nanomaterials: Synthesis, properties and applications. ;

Module 3 : Non-structural materials: Dielectric materials; dielectric constant and polarization, linear dielectric materials, capacitors and insulators, non-linear dielectrics, pyro, piezo and ferro-electrics properties;

Module 4 : Semiconductor: direct and indirect band gap, band diagrams, applications of semiconductors, degenerate and non-degenerate semiconductors, extrinsic and intrinsic semiconductors. Superconducting materials, Optical & Photoionic materials, electron-hole-recombination.

Module 5 : Biomaterials, property requirements for biomaterials, concept of biocompatibility, important biometallic alloys; Ti based, stainless steel.Intelligent materials.

Course outcomes: At the end of this course, the students would be able to:

1.Understand major types of special steels such as HSLA, TRIP, Dualand Tool steels.

2. Know the processing techniques of specials steels.

Essential Reading:

1. W.F. Smith, Principles of Materials Science and Engineering,McGraw Hill, New York (1994).
2. W.D. Callister, An Introduction Materials Science & Engineering, John Wiley & Sons (2007).

Supplementary Reading:

1. V. Raghavan, Material Science and Engineering, Prentice Hall of India, 2004.
2. R.Sharma, Sharma, Heat Treatment: principles and techniques, Prentice Hall of India, (2004).

Program Elective I : Structure and Properties of Materials (PM 1105)

Course objective: To develop an understanding of the basic principles of physical metallurgy and apply those principles to engineering applications.

Syllabus Content:

Module 1 : Crystal Structure: Space lattices, Bravais lattices and Reciprocal lattice concept. Miller Indices of planesand directions. ; Bonding in Solids: Ionic, Covalent, and Metallic bonding.

Module 2 : Theory of alloy formation, Solidsolution, Substitutional and interstitial solid solution, Hume Rothery Rules, Intermetallic compounds, Normalvalency compounds, Electron compounds, Interstitial compounds. ;

Module 3 : Imperfections: Point defects: vacancies,Interstitialcies, Dislocations: Edge & Screw dislocations, Burgers vector. ;

Module 4 : Binary Phase Diagrams: Isomorphous,Eutectic, Peritectic, Eutectoid, Monotectic&Syntectic systems. Phase rule and Lever rule. ; Iron-CementiteEquilibrium diagrams and its applications. ;

Module 5 : Diffusion: Fick's First and Second law of diffusion. Atomic modelofdiffusion.Grain boundary, surface and thermal diffusion.Kirkendall Effect, Grube method, Matanomethod,Interstitial diffusion. ; Nucleation: Homogeneous and Heterogeneous nucleation, Kinetics of nucleation. Growthand overall transformation kinetics.

Course Outcomes:

1.Understand the geometry and crystallography of crystalline materials using Bravais lattices and Miller Indices.
2.. Understand the basics of Microstructural aspects with the different processing of materials.
3. Understand the importance of structure-property correlation study of materials and its suitable applications.
4. Evaluate nucleation and growth kinetics of materials
5. Understand the impact of crystal structure and defects on properties of materials

Essential Reading:

1. V. Raghavan, Materials Science and Engineering, Prentice-Hall of India Private Limited (2003).
2. W.F. Smith, Principles of Materials Science and Engineering, McGraw Hill, New York (1994).

Supplementary Reading:

1. R.E. Reid Hill, Physical Metallurgy Principles- PWS-Kent Publishing (2004).
2. V. Singh, Physical Metallurgy, Standard Publisher (2008).
3. W.D.Callister, An Introduction Materials Science & Engineering, John Wiley & Sons (2007).
4. L.H. Van Vlack, Elements of Materials Science and Engineering, Addison Wisley, New York (1985).

Program Elective I : Powder Production and Processing (PM 1106)

Course Objective- To introduce students with fundamentals of powder metallurgy and its underlying mechanism, the reason to follow this route as compared to other production techniques and various techniques to produce a variety of industrial application powder product.

Syllabus Content-
Module 1: Production Techniques: Introduction, Different methods of powder production viz Milling, atomization, Reduction, Electrolysis, Carbonyl process.
Module 2:Sintering: Solid state sintering, Liquid phase sintering, Reaction sintering, Hot pressing, Hot isostatic pressing, Self-propagating combustion sintering, Sintering atmosphere.

Module 3:Characterization: Chemical composition, Structure, Morphology, Shape, Size, Distribution, Surface area, Powder flow, Apparent density, Tap density, Compressibility, Porosity.

Module 4:Powder Processing for various purposes: Powder mixing and blending, Compaction techniques, Uniaxial, Isostatic compaction, Extrusion, Forging, Rolling, casting,Tooling and Die design.Production of filters, self-lubricating bearings, gears, friction parts, electrical materials, sintering of carbide tools, fabrication difficulty of tungsten filament, synthesis and sintering of hydroxyapatite(HAP) and other bioceramics, powder metallurgy of stainless steel,

Module 5 : Application of powder metallurgy in Indian industries.

Recommended Books:

1. Randall M. German, Powder Metallurgy Science, Metal Powder Industires Federation, Princeton, New Jersey (1984).
2. ASM Hand book, Vol. 7: Powder Metallurgy, ASM International, (2010).
3. W.D. Kingery, H.K. Bowen and D.R. Uhlmann: Introduction to Ceramics, John Wiley & Sons, New York, (2009).
4. G. S. Upadhyaya: Powder Metallurgy Technology, Cambridge International Science Publishing, (2002)

CO 1-Understand the basics of powder production techniques, applications of powder processing techniques and its superiority for choice over other production techniques.
CO-2 Understand the fundamentals of powder sintering.
CO-3 Understand various characterization parameters associated with powder metallurgy.
CO-4 Understand the fabrication process of important powder metallurgy products as filters, die and tools, self-lubricating, gears, friction parts, electrical materials, bioceramics and similarthrough powder metallurgy.

Program Elective II: Mechanical Behaviour of Materials (PM 1107)

Course objective: To know the fundamental concepts of mechanical behavior of materials and to apply them to design the materials for various load-bearing structural engineering applications.

Syllabus Content:

Module 1: Dislocation Theory: Types of dislocations, Critical Resolved Shear Stress, Dislocations in FCC,BCC and HCP structures, Stress fields and energies of Dislocations, Forces on Dislocations, Cross-slip and climb, Interactions of Dislocations, Dislocation multiplication, Dislocation pile-up.

Module 2: Creep test: Creep curve, Android analysis, Structural changes during creep, deformation mechanism maps, Activation energy for steady state creep, Super Plasticity, fracture at elevated temperature, presentation of engineering creep data, prediction of log time properties, stress rapture test.

Module 3: Impact test: Introduction, notched bar impact test, Instrumented charpy test, signification of transition temperature, environment sensitive cracking(hydrogen embrittlement stress corrosion cracking, liquid metal embrittlement)

Module 4: Fracture Mechanics: Stain energy release rate, stress Intensity factor, Plane Strain fracture toughness test, R curves, Plane stress fracture toughness test.

Module 5: Rheology and Mechanical Properties of Polymer:

Mechanical models of viscoelastic behaviour, Glassy state, Glass transition temperature, Mechanical properties of crystalline polymers, Polymers involving large and small deformations, Fatigue crack growth in polycrystalline materials. **Mechanical Properties of Ceramics:** Mechanism of deformation, Strength and toughness of Ceramics, Creep and Fatigue failure of Ceramics.

Course Outcomes:
1.Interpret the relationship between structure of a material and its mechanical properties.
2. Apply the knowledge of creep and superplasticity phenomena to design processes for improved microstructure and properties.
3. Apply the fracture mechanics principles to determine the fracture toughness of brittle and ductile materials.
4. Select the appropriate processing route and alter the microstructures of various engineering materials to meet the design and application demands.

5. Analyze the various metallurgical factors affecting mechanical properties of different metals and alloys.

REFERENCES:

1) Elementary Dislocation Theory- J Weertman, Mac Millan
2) The Plastic Deformation of Metals- R W K Honeycombe, Edward Arnold
3) Fundamentals of Physical Metallurgy- J D Verhoeven, John Wiley
4) Mechanical Metallurgy- G E Dieter, McGraw Hill
5) Metals hand book- VOL.8, ASM
6) Deformation and Fracture Mechanics of Engineering Materials- R W Hertzberg, Wile

Program Elective II: Alloy Steels Technology (PM 1108)

Course objective: To know different types of alloys steel.

Syllabus Content:
Module 1: Low-carbon Mild steels: Introduction; cold forming steels, High strength packing steels; HSLA steels; Low-carbon Ferrite pearlite steels – structure property relation-ships, strengthening mechanisms, Formability of HSLA steels.
Module 2: Medium- High carbon ferrite-pearlite steels – structure property relationships, Bainitic steels; Low-Carbon bainitic steels-requirements, development and choice of alloying elements, Mechanical properties, microstructure and impact properties; High-Carbon bainitic steels.
Module 3: Ultra-high strength steels: Introduction, steels tempered at low temperatures, secondary hardening, thermo- mechanical treatments, rapid austenitizing treatments, structure-property relationships in tempered mantensite, cold-drawn pearlite steels, maraging steels.
Module 4: Stainless steels: Classification, Composition, Microstructures, Heat treatment an application.
Module 5: Tool steels and Heat resistant steels: Classification, Composition, Micro structure an Heat treatment and application.

Course outcomes: Upon completion of the course, the student will be able to:
1. Understand major types of special steels such as HSLA, TRIP,Tool steels.
2. Know the processing techniques of specials steels.
3. Selection of Special steels for specific engineering applications.

TEXT / REFERENCE BOOKS:
1. Physical Metallurgy and the Design of steels: F. B. Pickering, Applied Science publisher, London,1978.
2. The physical Metallurgy of steels: W. C. Leslie by Hemisphere Publishers Corporation, 1981.
3. Alloys Steels – Wilson.
4. Heat Treatment of steels – Rajan& Sharma

Essential Reading:
1. F.P. Edneral: Electrometallurgy of Steel and Ferro – Alloys, Vol. I, Mir Publishers, 1979.
2. R.W.K.Honeycomb: Steels, Microstructures and Properties, Edward Arnold.

Supplementary Reading:
1. G.Karuss, Steel Heat Treatments and Processing Principles, ASM.
2. P.G.Shewmon, Transformations in Metals, McGraw Hill.
3. Dr. S. Smith, Principles of Materials Science and Engineering, McGraw Hill.
4. J.D. Verhoeven, Fundamentals of Physical Metallurgy, John Wiley.

Program Elective II : Nanostructured Materials (PM 1109)

COURSE OBJECTIVES:: This course will illustrate about the reasons for changing the properties of materials when their size reduces to nano-dimension. It will further discuss about the processing, characterization and application of wide range of nanostructutred materials.

Syllabus Content:

Module 1: Introduction: Micro- and Nano-structures, properties and length scales of microstructures, nano-materials and nano-composites. Manipulation of surfaces at nanoscales.

Module 2: Processing of nano structured materials

Top-down and bottom-up approaches (wet chemical, ball milling, self assembly, biomimetic, micro-machining, lithography processing).

Module 3: Characterization: Nano-diffraction and HREM, Scanning probe microscopy: Scanning tunneling microscopy and spectroscopy, Atomic-, Magnetic-, Friction- and Electrical Force Microscopy.

Module 4: Evaluation of surface characteristics.Electric and magnetic properties.Mechanical behavior using Dynamic Ultra- microhardness and nanohardness tests.

Module 5: Applications : Data storage, optoelctronic, environmentally sensitive coatings, diagnostic, drug delivery, imaging and therapy.Future potential.

OUTCOME OF THE COURSE:

Students will be able to impart knowledge on nanostructured materials.

TEXTBOOKS:

1. C.P. Poole Jr., F.J. Owenes, Introduction to nano-technology, Wiley Interscience.
2. Bhusan (Ed.) Nanotechnology, Springer.
3. H. Fujita (Ed.), Micromechanics as tools for nanotechnology, Springer International Edition.

REFERENCE BOOKS:

1. M.V. Gandhi and B.S. Thompson, Smart Materials and Structures, Chapman and Hall.
2. G.L. Hornyak, H.F. Tibbals, J.Dutta, J.J. Moore, Introduction to Nanoscience and Nanotechnology, CRC Press

Program Elective II : ADVANCED MATERIALS ENGINEERING (PM 1110)

COURSE OBJECTIVES:

1. To give fundamental knowledge about type of materials, their usage, properties and characteristics, which are important in engineering design. To provide a theoretical background about the analysis of behavior of engineering materials by emphasizing important relationships between internal structure and properties.
2. Use the fundamental science and engineering principles relevant to materials that include the relationships between nano/microstructure, characterization, properties, processing, performance and design of materials.
3. To predict and control material properties through an understanding of atomic, molecular, crystalline, and microscopic structures of engineering materials.

Module-1: Structure of metals: Introduction, SC, BCC,FCC, HCP Crystal structure, Coordination number, Relationship between lattice parameter and atomic radius, Packing factor and density calculations, crystal system and Bravais lattices**,** Space lattices, Miller Indices of planes and directions.

Module 2 : Imperfections in metals and alloys: Introduction, types of imperfections Point defects, Vacancies, Interstialcy, Substitutional impurity, Interstitial impurity, Schottky and Frenkel imperfections, line imperfections, Dislocations; Edge & Screw dislocations; Burgers vector, surface imperfection, grain boundary, Tilt boundary, Twin boundary, Stacking Foults.

Module 3 : Iron-Cementite Equilibrium , Eutectic, Peritectic, Eutectoid, Monotectic and Syntectic systems, Phase rule and Lever rule, TTT and CCT diagrams. Heat-Treatment of steels: Annealing, Normalizing, Hardening and Tempering of steels.

Module 4: Deformation of material: Recovery recrystallization and grain growth, Mechanical properties of materials: Tensile, Impact , Fatigue and Creep of metals.

Module 5: Diffusion in metals: Introduction, Fick's First and Second law of diffusion, The Kirkendal effect. Types of diffusion, Diffusion mechanism, application of diffusion. Introduction, classification of polymers, composite and ceramics, Structure and properties of polymers and composites, ceramics materials and applications.

Course Outcomes : Upon Successful completion of this course, each student should be able to:

- To familiarize with the concept of material science and engineering of different metals, ceramics and composites.
- To understand the basic structures of metals and alloys
- To develop the ability of analyzing complex engineering problems associated with different materials
- To be competent in designing components and processes for particular engineering applications.
- Analyse the binary phase diagrams of alloys including Fe-Fe3C, brass, and bronze
- Identify the crystal structures of metallic materials
- An ability to use modern techniques, skills, and engineering tools appropriate to materials research and engineering
- An integrated understanding of structure, properties, processing and performance of materials systems.

Text / Reference Books :

1. V. Raghavan. (PHI); Materials Science and Engineering - A First Course
2. A. Guy. ; Introduction to Materials Science; McGraw Hill
3. Van Vlack.; Materials Science
4. John Wolf ; Materials Science & Engineering
5. William Callister ; Introduction to Materials Science & Engineering
6. Askeland. D.R.; Introduction to Materials Science & Engineering
7. Shackleford.; Materials Science

Program Elective III : Physical Metallurgy of Alloy Steels (PM 1111)

Course objective: To comprehend the basic principles of physical metallurgy of alloy steels and apply those principles to demanding engineering applications.

Syllabus Content:
Module 1: Effect of alloying elements on steels.Hot rolling of structural steels. High Strength Low Alloy (HSLA) steels;Controlled rolling of HSLA steels. Strengthening mechanisms in HSLA steels: Grain size control and precipitation strengthening Ausforming, Isoforming;

Module 2: Dual phase steels: Metallurgy and Thermo mechanical processing.

Module 3: Stainless steels: Austenitic, Ferritic, Martensitic Stainless Steels. Schaeffler diagram.Effect of martensitic and other phases in Austenitic Stainless Steels.Sensitization of Austenitic Stainless Steels.Intermetallic phases and4750 C embrittlement in Ferritic Stainless Steels.Martensitic Stainless Steel, their heat treatment Precipitation Hardening Stainless Steels. ; Duplex stainless steels. ;

Module 4: High speed steels: Their composition and heat treatment.

Module 5: Hadfied steels: their composition, heat treatment. Ball bearing steels. Marging steels: Their composition, heattreatment.

Course outcome: After the completion of this course, the student will be able to:

1. Identify the phases present in different alloy systems by analyzing the phase diagrams.
2. Design the heat-treatment cycles for different alloy systems to obtain the desired phases.
3. Define various heat treatment procedures for variety of engineering materials and their importance in materials behaviour.

Essential Reading:

1. R.W.K. Honeycombe and H K D H Bhadesia, Steels Microstructure & Properties – (2nd Edition) Edward Arnold, 1995, ISBN No. 0-340-58946-9.
2. I Tamura, H.Sekine, T Tanaka, and C.Ouchi, Thermo Mechanical Processing of High Strength Low Alloy Steels, Butterworths (1988), ISBN No. 0-408-11034-1.
3. G Kranss, Steels Heat Treatment and Processing Principles, ASM International, Materials Park, Ohio 44073,

Supplementary Reading:

1. HSLA steels Metallurgy and Applications (Conference Proceedings), ASM International (1986), ISBN No. 0-87170-299-0.
2. C.R. Brooks, Principles of the Heat Treatment of Plain Carbon and Low Alloy Steels, ASM International, (1996), ISBN No. 0-87170-538-9.

Program Elective III : Joining of Materials (PM 1112)

COURSE OBJECTIVES:

1. To teach the fundamental concepts of welding technology and its metallurgy.
2. To teach the different types of joining processes.
3. To teach the various welding defects and it's remedial.
4. To Teach the advanced welding techniques.

Course details:

Module 1: Introduction: theory and classification of welding and other joining processes.

Manual metal arc welding: equipment, electrodes for structural steels, coating constituents and their functions. Types of coatings, current and voltage selection for electrodes, power sources, conventional transformers, rectifiers, current and voltage. Influence of power sources on welding. Metal transfer and Heat transfer.

Module 2: Submerged arc welding: process details, consumables for welding mild steel, variations in the process. Gas metal arc welding or MIG/MAG welding: process details, shielding gases, electrode wires, sizes and current ranges.

Module 3: TIG welding: process details, power source, electrode sizes and materials, current carrying capacity of electrodes. Shielding gases, applications.

Module 4: Resistance welding: principles, applications, process details and working principle of spot, seam and projection welding, electrode materials, shapes of electrode, electrode cooling, selection of currents, voltages; welding metallurgy of carbon and alloy steels, cast irons, stainless steels, Al- and Cu- based alloys. Weldability and heat affected zones. Welding defects and detection techniques.

High energy density welding techniques such as Laser Welding, Electron Beam Welding, their specific applications and advantages.

Module 5: Soldering and brazing: difference between processes, consumables, methods of brazing, fluxes used, their purposes and flux residue treatment.

COURSE OUTCOMES:

1. Classify and differentiate welding processes.
2. Explain heat flow in welding.
3. Identify various defects and remedial measures in weldment.
4. Appreciate the importance of welding metallurgy.

Reference Books:

1. Lancaster, Allen and Unwin, Metallurgy of Welding,

2. Little, R.L., Welding and Welding Technology, TMH

3. Norrish, J. and Woodhead, Advanced Welding processes.

Program Elective III : Computational Methods for Metallurgy (PM 1113)

COURSE OBJECTIVES: The course is intended to elucidatethe details of various numerical methods including solutions of ordinary and partial differential equations and basic modelling and simulation techniques with special emphasis on computational applications in metallurgical engineering.

Syllabus Content:

Module 1: Error analysis and evaluation of functions, Numerical differentiation and integration.

Module 2: Root finding problems: solution of linear and non-linear systems of equations, Minmax problems: minimization and maximization of functions,Linear and non-linear least squares optimization and Interpolation with special emphasis on computer implementation and applications in metallurgical engineering.

Module 3: Initial and boundary value problems in ordinary and partial differential equations.
Module 4: Introduction to finite difference (FDM) and finite element (FEM) methods. Applications in materials processing: heat transfer and solidification; metal forming processes etc.

Module 5: Simulation of simple metallurgical systems using Monte-Carlo Simulations and simulated annealing.Simulation of microstructure evolution and grain growth in metals and alloys.

OUTCOME OF THE COURSE:
1. At the conclusion of this course, student would be able to select suitable numerical method(s)/technique(s) and develop necessary computer algorithm(s) for a chosen problem.

TEXTBOOKS:
1. W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery: Numerical Recipes -The art of scientific computing, 3rd ed., Cambridge
2. S.C.Chapra and R.P.Canale, Numerical Methods for Engineers: With personal computer applications, McGraw-Hill (International Edition), 1984.

REFERENCE BOOKS:
1. S.Kobayashi, Y.T.Im and T.Altan, Metal forming and finite element method, Oxford Univ. Press, New York, 1989.
2. C.R.Boer, N.Rebelo, H.Rydstad and G.Schroder, Process Modelling of Metal Forming and Thermomechanical Treatment, Springer-Verlag, 1986.
3. D. Mazumdar and J.W. Evans: Modelling of Steel Making Processes, CRC.

Program Elective III : ADVANCED FOUNDRY TECHNOLOGY(PM 1114)

Course Objective- to introduce students with details of various steps in foundry viz moulding, gating systems and mathematical modelling of alloys/metals under different cooling conditions.

Syllabus content-

Module 1: Basic steps in foundry: Preliminary introduction to various steps in foundry, pattern making and types, mould sand preparation, binders and additives, tools to prepare moulding sand, cores, gating system and its types. (6 hours)

Module 2: Foundry tools and methods: Pattern types, materials and various dimensional allowances, types of sand used and its various useful relevant properties viz grain size, shape and its distribution and its effect on casting during solidification. Binders and their characteristics, moulding practices- green and dry, carbon dioxide and shell process.

Module 3: Core making. Tools used like mixer, muller, jolting, squeezing, jolt squeezing, slinging, blowing etc. Gating system and its type. Designing Gating system. gating ratio; pressurized and un- pressurized systems; types of gates; Slag traps and filters etc. with reference to different cast metals and alloys. (14 hours)

Module 4: Solidification analysis in foundry: Thermodynamics of solidification, Nucleation and growth, Pure metal solidification, Gibbs Thomson effect, Alloy Solidification: Mathematical Analysis of redistribution of solute during solidification, Constitutional under cooling, Dendrites growth, Multi phase solidification: eutectic and peritectic, Modeling of solidification under different conditions. (14 hours)

Module 5: Industrial Practice: melting furnaces and processes for the production of cast irons and steel castings, special problems in heat treatment to ferrous castings, sand practice for iron and steel casting production, Numerical problems and computers in foundry. (8 hours)

Recommended Books/Texts:

J. Campbell, Castings, Butterworth, 1991, London Heine and Rosenthal, Principles of Metal Casting; 1955, McGraw Hill, NY; Solidification of Metals, W. C. Winegard, Institute of Metals 1964.

D.S. Porter & K.E. Esterling, Phase transformation in metals and alloys, Chapman & Hall, 1981.

W. Kurtz and D.J. Fischer, Principles of Solidification, edition - 3, Trans Tech Publications, 1992.

CO-1: To get students acquainted with basic steps of foundry and such industrial example.

CO-2: To understand details of Mould/gating system and Mold sand/binders, additives preparation.

CO-3: To understand the Mathematical modelling of solidification of metals/alloys and variations under different cooling conditions.

RMC 1101	Compulsory paper	Research Methodology & IPR	2

Course Content

Unit-1: Research Problem and Scope for Solution: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations.

Unit-2: Format: Effective literature studies approaches, analysis, Plagiarism, Research ethics. Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee.

Unit-3: Process And Development: Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, patenting under PCT.

Unit-4: Patent Rights: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Unit-5: New Developments In IPR: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Text Books:

1. Stuart Melville and Wayne Goddard, "*Research methodology: an introduction for science & engineering students*"
2. Wayne Goddard and Stuart Melville, "*Research Methodology: An Introduction*"
3. Ranjit Kumar, 2nd Edition, "*Research Methodology: A Stepby Step Guide for beginners*"

Reference Books:

1. Halbert, "*Resisting Intellectual Property*", Taylor & Francis Ltd, 2007.
2. Mayall, "*Industrial Design*", McGraw Hill, 1992.
3. Niebel, "*Product Design*", McGraw Hill, 1974.
4. Asimov, "*Introduction to Design*", Prentice Hall, 1962.
5. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " *Intellectual Property in New Technological Age*", 2016.
6. T. Ramappa, "*Intellectual Property Rights Under WTO*", S. Chand, 2008

SEMESTER II

Core III : Phase Transformation of Materials (PM 2101)

Course objective: To study the phase changes that occurs during both thermal and thermo mechanical treatments.

Syllabus Content:

Module 1: Introduction and classification of phase transformations; Diffusion in solids: phenomenological approach and atomistic approach. Nucleation and growth theories of vapour to liquid, liquid to solid, and solid to solid transformations; homogenous and heterogeneous strain energy effect during nucleation; interface-controlled growth and diffusion controlled growth; Overall transformation kinetics.

Module 2: Principles of solidification, Evolution of microstructures in pure metals and alloys. Precipitation from solid solutions:

Module 3: Type of Precipitation reactions, Precipitation sequence and age hardening, Spinodal decomposition, Iron-carbon diagram, Iron-carbon alloy system, Nucleation and growth of pearlite, cooling of hypo-eutectoid, eutectoid and hyper-eutectoid, Bainitic transformation, Martensitic Transformation, Massive Transformation, Order-disorder transformation, Phase transformation of some common non-ferrous metals and alloys.

Module 4: Transformation in quartz, alumina and zirconia and their significance.Transformation toughening mechanism and significance in engineering applications; PSZ, TZP and ZTA.

Module 5: Transformation in solid state sintering and fusion sintering; microstructural changes. Amorphous to crystalline conversion in glass in engineering significance.

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

1. Understand the theory of nucleation and growth kinetics of solidification
2. Explain the phase transformation reactions of Fe-Fe3C system.

References:

1. Porter and Easterling, Phase Transformations in Metal and Alloys, Nelson Thornes.
2. Zakharov, Heat Treatment of Metals, CBS.
3. Raghavan, Solid State Phase Transformations, PHI.
4. Christian, the theory of Transformations in Metals and Alloys, Pergamon Press.
5. Buerger, Phase Transformations in Solids, john Wiley.
6. Introduction to Ceramics, Kingery, john Wiley and Sons.
7. Introduction to Zirconia, R.Stevens, Magnesium Electron.
8. Handbook of Ceramics, Vol. 2, 3, 4, S.Kumar

Core IV: CHARACTERISATION OF MATERIALS (PM 2102)

COURSE OBJECTIVES: The students will be familiar with various characterization tools and techniques for microstructural, structural and chemical characterization of materials. The course will be first step to advanced structural, microstructural and chemical analysis for post graduate students.

Syllabus Content:

Module 1: Chemical bonding, Fundamentals of crystallography, Reciprocal lattice, Structures in metals, Inorganiccompounds, Polymers, Silicate glasses, Stereographic projection. Properties of materials; physical, chemical, electrical, optical and magnetic properties.

Module 2: Microscopic and diffraction techniques: Abbe's criteria, Resolution and resolving power of microscope,Rayleigh's criteria of resolution, Optical microscope, Aberrations, Electron interaction with materials. Electron diffraction, Electron microscope,

Module 3: SEM: principle of operation, mode of operation. TEM: principle of operation,sample preparation, mode of operation, advanced microscopic techniques: AFM, STM, EELS. X-ray diffraction:Principle of X-ray diffraction, Bragg's law, structure determination.

Module 4: Thermal characterization techniques: Theory, Thermo Gravimetric Analysis (TGA), Instrumentation, Applications,Differential Thermal analysis (DTA), Apparatus, Methodology, Applications, Differential Scanning Calorimeter(DSC), Applications, Dilatometer.

Module 5: Chemical characterization techniques: Principle underlying techniques, Infrared spectroscopy (IR), Ramanspectroscopy, Mossbauer spectroscopy, Nuclear magnetic resonance spectroscopy (NMR), Emissionspectroscopy (Chromatography techniques).

OUTCOME OF THE COURSE:

The course will enable students to analyse structures, microstructures, chemistry of materials by basic techniques using optical, electron and x-ray, radiation through various microscopy and diffraction techniques. The course will help students to understand concepts on structural metallurgy, phase transformations, diffraction and microscopy.

Essential Readings:

1. Material Characterization, Metals Handbook, Vol 10, Ruth E. Whan, ASM, 1986.
2. Characterization of Materials, Elton N Kaufmann, Willey Publishers, 2003.

Supplementary Readings:

1. The structure and properties of solids, P. J. Grundy and G. A. Jones, Edward Arnold, 1975.
2. Elements of X-ray diffraction, B. D. Cullity, Addison-Wesley publishing company, 2002.
3. Chemical characterization of materials, B. M. Rao, Himalaya publishing house, 2000.
4. Scanning electron microscopy and X-ray microanalysis, J. I. Goldsetin, , C E. Lyman, D. E. newbury, springer, 2003

Program Elective IV: Composite Materials (PM 2103)

Course objectives: To understand the fundamentals (structure, properties and processing) of composite materials to appreciate its advantages and limitations and to apply those fundamentals for selecting and developing ceramic materials for different engineering applications.

Syllabus Content:

Module 1: INTRODUCTION: Definition – Classification and characteristics of Composite materials. Advantages and application of composites.Functional requirements of reinforcement and matrix.Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

Module 2: REINFORCEMENTS: Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers. Properties and applications of whiskers, particle reinforcements. Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures. Isostrain and Isostress conditions.

Module 3: Manufacturing of Metal Matrix Composites: Casting – Solid State diffusion technique, Cladding – Hot isostaticpressing.Properties and applications. Manufacturing of Ceramic Matrix Composites: Liquid Metal Infiltration – Liquid phase sintering. Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving. Properties and applications.

Module 4: Manufacturing of Polymer Matrix Composites: Preparation of Moulding compounds and prepregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding. Properties and applications.

Module 5: Strength: Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hygrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

Course outcome: After the completion of this course, the student will be able to:

1. Know the structure and properties of different composite materials.
2. Understand the phase diagrams and comprehend the phase transformations in composite materials.
3. Understand the testing methods for evaluating the mechanical properties of composite materials.

Text books:

1. Material Science and Technology – Vol 13 – Composites by R.W.Cahn – VCH, West Germany.

2. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramaniam, John Wiley & Sons, NY, Indian edition, 2007.

References:

1. Hand Book of Composite Materials-ed-Lubin.

2. Composite Materials – K.K.Chawla.

3. Composite Materials Science and Applications – Deborah D.L. Chung.

4. Composite Materials Design and Applications – Danial Gay, Suong V. Hoa, and Stephen W. Tasi.

Program Elective IV: Polymer Engineering (PM 2104)

Course objective: To develop the basic knowledge of materials particularly polymers other than conventional metals and alloys to apply them to advance engineering applications

Syllabus Content:

Module 1: Basic concepts of polymers, Monomer, Polymerization, Molecular orientation, Copolymers, Polymer bends and alloys,

Module 2: Thermoplastic and Thermosetting polymers, Polymer morphology, Molecular Weight, additive, Fillers.

Module 3: Mechanism and kinetics of Crystallization, Melting.Viscoelastic behavior, Molecular Theory of Viscoelasticity, Glassy and Rubbery states, Glass Transition Temperature.

Module 4: Properties of Elastomers, Thermodynamic Aspects, Network effects, Resilience of Elastomers. Deformational behavior of polymers, Stress-relaxation, Time-temperature superposition, Polymer yield and ductility, Nature of fracture, Mechanical properties of common and engineering polymers.

Module 5: Application of polymers (Photoionic, Non-liners optics, Thermorecording etc.) and Reinforced Polymers, Toughened Polymers.

Course outcomes:

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

1. Select different materials other than conventional metals and alloys for specific engineering applications.
2. Solve the materials problems associated with the weight reduction through the appropriate choice of polymers.

References:

1. Young and Lovell, Introduction to Polymers, Nelson Thornes.
2. Fried, Polymer Science and Technology, PHI.
3. Cowie, Polymers: Chemistry and Physics of Modern Materials, Nelson Thornes.
4. Odian, Principles of Polymerization, John Wiley and Sons.
5. Bowden and Turner, Electronic and Photoionic Applications of Polymers, American Chemical Society.
6. Allen and Bevington, Comprehensive Polymer Science, Pergamon Press.

Program Elective IV : Corrosion and Protection of Materials (PM 2105)

COURSE LEARNING OBJECTIVES

- To teach the fundamental concepts of electrochemical reactions and its principle behind the corrosion.
- To teach the different types of corrosion and mechanism.
- To teach the corrosion test procedure and corrosion protection.

Module 1 : Principles of corrosion phenomenon: Thermodynamics and kinetics: emf/galvanic series, Pourbaix diagram, exchange current density, passivity, Evans diagram, flade potential.
Module 2 : Different forms of corrosion: atmospheric/uniform, pitting crevice, intergranular, stress corrosion, corrosion fatigue, de-alloying, high temperature oxidation-origin and mechanism with specific examples.
Module 3 : Corrosion testing and monitoring: Non-Electrochemical and Electrochemical methods: weight loss method, Tafel Linear polarization and Impedance techniques, Lab, semi plant & field tests, susceptibility test.
Module 4 : Corrosion prevention through design, coatings, inhibitors, cathodic, anodic protection, specific applications, economics of corrosion control.
Module 5 : Corrosion & its control in industries: Power, Process, Petrochemical, ship building, marine and fertilizer industries. Some case Studies-Corrosion and its control in different engineering materials: concrete structures, duplex, super duplex stainless steels, ceramics, composites and polymers. Corrosion auditing in industries, Corrosion map of India.

COURSE OUTCOMES:

1. Explain the principles of corrosion.
2. Evaluate corrosion mechanisms from first principles.
3. Suggest suitable techniques for corrosion monitoring and its prevention.
4. Discuss the mechanism of high temperature oxidation

Text Books.

1. Fontana. M.G., Corrosion Engineering, Tata McGraw Hill, 3rd Edition, 2005.
2. Jones.D.A. Principles and Prevention of Corrosion, 2nd Edition, Prentice Hall, 1996.
3. Corrosion: Metal / Environment Reactions, Volume 1, L.L. Shreir, R.A. Jarman, G.T. Burstein, Butterworth-Heinemann, 1994.
4. Principles and Prevention of Corrosion, Denny A. Jones, Pearson, 1995.

Program Elective V: X-Ray and Electron Microscopy (PM 2106)

OBJECTIVES: The students will be familiar with various characterization tools and techniques for microstructural, structural and chemical characterization of materials. The course will be first step to advanced structural, microstructural and chemical analysis for post graduate students.
Syllabus Content:

Module 1: Properties, lattice and its relation with diffraction; factors affecting the intensity of diffracted beam, calculation of integrated intensity; estimation of stress, texture and other defects; interactions between electrons and matter;
Module 2: principles of transmission of electron microscopy, elements of electron optics, electron lenses – their aberrations, resolving powers, depth and field of focus;
Module 3: kinematical theory of electron diffraction, geometry of electron diffraction and their applications, micro-diffractions, trace analysis, bright-field and dark-field image contrast;
Module 4: principles and applications of SEM, principles of microanalysis.

OUTCOME OF THE COURSE: The course will enable students to analyse structures, microstructures, chemistry of materials by basic techniques using optical, electron and x-ray, radiation through various microscopy and diffraction techniques. The course will help students to understand concepts on structural metallurgy, phase transformations, diffraction and microscopy.

References:

1. B.D.Cullity, Elements of X-Ray Diffraction, Addison Wesley.
2. C.S.Barett and T.M. Massalski, Structure of Metals, McGraw Hill.
3. S.K.Chatterjee, X-ray Diffraction, Its theory and Applications, PHI.
4. Materials Characterization Techniques, (eds.) G. Sridhar, et al. National Metallurgical Laboratory, Jamshedpur.

Program Elective V : Mechanical Working of Materials (PM 2107)

Course objective: To know the concepts of metal forming and associate technologies and apply them to the conventional and advanced materials manufacturing for various structural applications.

Syllabus Content:

Module 1: Fundamentals of Metal working processes: Theory of plasticity and yield – criterion, Workability Tests, Hotworking, Cold working and warm (semi-hot) working of metals, structure of cold worked and hot worked metals.;

Module 2: Rolling of Metals: Various rolling Mills and rolling processes, Theories of Hot and Cold rolling Defects inrolling and their remedial measures. Rolling Mill Control, Concepts of roll-pass-design, Roll pass design ofsome simple shapes like Flat products, Blooms, rounds, etc. ;

Module 3: Forging of Metals: Type of forging processes,Die design, Various forging equipments, Forging defects and their remedies, Load and energy requirementsin Forging, Forging of Rail wheels and tyres. ; Extrusion of Metals: Types of Extrusion processes, Metal flow inExtrusion process, Variables in extrusion, Extrusion defects and their remedies, Load and energy requirements,sheathing and cladding by Extrusion. ;

Module 4: Drawing of Metals: Type of operation, Dies, Load and Energy requirement,Drawing of seamless Tubes. ; Sheet Metal Forming: Operations, Equipment, Technology, Defects and their remedies. ;

Module 5: Non conventional Processes: High Energy rate forming processes Explosive forming of Metals,Electromagnetic forming.

Course outcomes: At the end of this course, the students would be able to:

1. Apply the concept of plastic deformation for metals and alloys to convert them in to useful shapes for intended engineering applications .
2. Differentiate the various metal forming technology and choose the appropriate one for required engineering applications.
3. Classify various metal forming technology (forging, rolling, extrusion etc.) and associated forming equipments.

Essential Reading:

1. G.E. Dieter, Mechanical Metallurgy.
2. A.Ghosh& A. Mallick. Manufacturing Sciences.

Supplementary Reading:

1. P.Polukhin, N.Fedosov, A.Korolyov& Y. Matveyer, Rolling Mill Practice, Making Shaping and Treating of Steel.

Program Elective V: Functional Materials (PM 2108)

Course objective: To develop the basic knowledge offunctional materials other than conventional metals and apply them to advance engineering applications

Syllabus Content:

Module 1:: Characteristics and types of functional materials.Crystal structure and Properties. – Effect of size on properties, effect of interfaces on properties.

Module 2: :Band structure, Semiconductor devices – Theory, examples and applications of Optically active materials

Module 3: Dielectrics, piezo- and ferroelectric materials

Module 4: Magnetic materials and storage applications, Smart materials

Module 5 : Applications in electronic, communication, aerospace, automotive, energy industries

Course outcomes: At the end of this course, the students would be able to:

1. Describe the selection criterion for polymers and composites for various engineering applications .

2. Analyze different microstructure of functional materials and alter them according to application requirements

Suggested books

1. Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic applications; Deborah D L Chung, World Scientific Publishing, 2010

Program Elective V : Advances Non-Ferrous Technology (PM 2109)

Course objectives:

Study the principles of extraction and refining processes of non ferrous metals from their ores and apply the concepts to make tailor made materials for given engineering design and applications. To develop understanding to know the associated principles of different processes of extraction.

Course Details :

Module 1 : General methods of extraction of metals from oxides and Sulphides; Extraction of Metals by Pyro,Hydro and Electro Metallurgy techniques with emphasis on the physico-chemical principles involved.Kinetics of leaching of ores and the effects of operation variables. (5 hrs)

Module 2 : Aluminium ores, Aluminium: Bayer's process and factors affecting its operation; Hall – Heroult process: principle & practices, use of electrodes, anode effect; Refining of Aluminium; Alternative methods of Alumina and Aluminium production. (5 hrs)

Module 3 : Copper: Extraction of copper from sulphide ores by pyrometallurgical process, Refining and uses. Newer process for copper extraction, hydrometallurgy process of copper. (5 hrs)

Module 4 : Zinc: Pyrometallurgical extraction of zinc; principles and practices of roasting, sintering and smelting; Hydrometallurgy of zinc. Lead: Refining and typical flowsheet of plant in production of lead , Blast furnace smelting, uses. (5 hrs)

Module 5 : Simplified flowsheet for extraction of metals Ti, Mg, U and Th, Tin, Ni . Electroplating-Principles of Electrode-position of Metals and alloys, Throwing power, Electroless plating, Electroforming, Anodizing. (5 hrs)

References:

1. Extraction of Non-ferrous Metals, Affiliated East- West Press, 2001– H. S. Ray, K. P. Abraham and R. Sridhar
2. K Grjotheim & B J Welch: Aluminum Smelter Technology, Aluminum – Verlag, 2nd Edn. 1988.
3. A K Biswas & W G Davenport: Extractive Metallurgy of Copper, Pergamon, 4th Edn. 2002.
4. W H Dennis, Metallurgy of Non – Ferrous Metals, Pitman, London, 1954.
5. J N Anderson & P Queneau, Pyrometallurgical Processes in Non – Ferrous Metallurgy, Gorden & Breach, New York, 1967.
6. N Sevryukov, Non – Ferrous Metallurgy, Trans. By I V Savin, Mir Publishers, Moscow, 1975.
7. J L Bray, Non – Ferrous Production Metallurgy, John Wiley, New York.
8. R D Pehlke, Unit Processes of Extraction Metallurgy, Elsevier, Amsterdam, 1982.

Course outcomes: At the end of this course, the students should be able to:

CO1: Define the general principles of extraction of metals from oxides and sulphides;
CO2: Draw the flow sheets for the extraction of non-ferrous metals from their ores.
CO3: Discuss the effect of a change in process parameters of different extraction processes.
CO4: Apply the refining processes for Aluminium, copper, zinc, lead, uranium, magnesium nickel and titanium and applications.

Open Elective I: Business Analytics (PM 2110)

Course Objective

1. Understand the role of business analytics within an organization.
2. Analyze data using statistical and data mining techniques and understand relationships between the underlying business processes of an organization.
3. To gain an understanding of how managers use business analytics to formulate and solve business problems and to support managerial decision making.
4. To become familiar with processes needed to develop, report, and analyze business data.
5. Use decision-making tools/Operations research techniques.
6. Mange business process using analytical and management tools.
7. Analyze and solve problems from different industries such as manufacturing, service, retail, software, banking and finance, sports, pharmaceutical, aerospace etc.

Syllabus Content:

Module 1: Business analytics: Overview of Business analytics, Scope of Business analytics, Business Analytics Process, Relationship of Business Analytics Process and organisation, competitive advantages of Business Analytics.

Statistical Tools: Statistical Notation, Descriptive Statistical methods, Review of probability distribution and data modelling, sampling and estimation methods overview.

Module 2: Trendiness and Regression Analysis: Modelling Relationships and Trends in Data, simple Linear Regression.

Important Resources, Business Analytics Personnel, Data and models for Business analytics, problem solving, Visualizing and Exploring Data, Business Analytics Technology.

Module 3: Organization Structures of Business analytics, Team management, Management Issues, Designing Information Policy, Outsourcing, Ensuring Data Quality, Measuring contribution of Business analytics, Managing Changes.

Descriptive Analytics, predictive analytics, predicative Modelling, Predictive analytics analysis, Data Mining, Data Mining Methodologies, Prescriptive analytics and its step in the business analytics Process, Prescriptive Modelling, nonlinear Optimization.

Module 4: Forecasting Techniques: Qualitative and Judgmental Forecasting, Statistical Forecasting Models, Forecasting Models for Stationary Time Series, Forecasting Models for Time Series with a Linear Trend, Forecasting Time Series with Seasonality, Regression Forecasting with Casual Variables, Selecting Appropriate Forecasting Models.

Monte Carlo Simulation and Risk Analysis: Monte Carle Simulation Using Analytic Solver Platform, New-Product Development Model, Newsvendor Model, Overbooking Model, Cash Budget Model.

Module 5: Decision Analysis: Formulating Decision Problems, Decision Strategies with the without Outcome Probabilities, Decision Trees, The Value of Information, Utility and Decision Making. Recent Trends in : Embedded and collaborative business intelligence, Visual data recovery, Data Storytelling and Data journalism.

Course Outcomes
1. Students will demonstrate knowledge of data analytics.
2. Students will demonstrate the ability of think critically in making decisions based on data and deep analytics.
3. Students will demonstrate the ability to use technical skills in predicative and prescriptive modeling to support business decision-making.
4. Students will demonstrate the ability to translate data into clear, actionable insights.

References:
1. Business analytics Principles, Concepts, and Applications by Marc J. Schniederjans, Dara G. Schniederjans, Christopher M. Starkey, Pearson FT Press.
2. Business Analytics by James Evans, persons Education.

Open Electives I: Industrial Safety (PM 2111)

Course Objective:

Student will be able to learn

1. The areas of hazards and sensitive places in Industries which need to be careful visit
2. What necessary steps to be taken to prevent the hazards and damage in industries or to reduce the risk of occurrence of hazards

Course Outcomes:

1. Safety skills enhancement in students and professionals.
2. Knowledge and skills of curbing hazards and leadership qualities
3. Pre alertness while doing work

Syllabus Content:

Module 1: Industrial safety: Accident, causes, types, results and control, mechanical and electrical hazards, types, causes and preventive steps/procedure, describe salient points of factories act 1948 for health and safety, wash rooms, drinking water layouts, light, cleanliness, fire, guarding, pressure vessels, etc, Safety color codes. Fire prevention and firefighting, equipment and methods.

Module 2: Fundamentals of maintenance engineering: Definition and aim of maintenance engineering, Primary and secondary functions and responsibility of maintenance department, Types of maintenance, Types and applications of tools used for maintenance, Maintenance cost & its relation with replacement economy, Service life of equipment.

Module 3: Wear and Corrosion and their prevention: Wear- types, causes, effects, wear reduction methods, lubricants-types and applications, Lubrication methods, general sketch, working and applications, i. Screw down grease cup, ii. Pressure grease gun, iii. Splash lubrication, iv. Gravity lubrication, v. Wick feed lubrication vi. Side feed lubrication, vii. Ring lubrication, Definition, principle and factors affecting the corrosion. Types of corrosion, corrosion prevention methods.

Module 4: Fault tracing: Fault tracing-concept and importance, decision treeconcept, need and applications, sequence of fault finding activities, show as decision tree, draw decision tree for problems in machine tools, hydraulic, pneumatic,automotive, thermal and electrical equipment’s like, I. Any one machine tool, ii. Pump

iii. Air compressor, iv. Internal combustion engine, v. Boiler, vi. Electrical motors, Types of faults in machine tools and their general causes.

Module 5: Periodic and preventive maintenance: Periodic inspection-concept and need, degreasing, cleaning and repairing schemes, overhauling of mechanical components, overhauling of electrical motor, common troubles and remedies of electric motor, repair complexities and its use, definition, need, steps and advantages of preventive maintenance. Steps/procedure for periodic and preventive maintenance of: I. Machine tools, ii. Pumps, iii. Air compressors, iv. Diesel generating (DG) sets, Program and schedule of preventive maintenance of mechanical and electrical equipment, advantages of preventive maintenance. Repair cycle concept and importance

Reference:

1. Maintenance Engineering Handbook, Higgins & Morrow, Da Information Services.
2. Maintenance Engineering, H. P. Garg, S. Chand and Company.
3. Pump-hydraulic Compressors, Audels, Mcgrew Hill Publication.
4. Foundation Engineering Handbook, Winterkorn, Hans, Chapman & Hall London.

Open electives I: Operations Research (PM 2112)

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

1. Students should able to apply the dynamic programming to solve problems of discreet and continuous variables.
2. Students should able to apply the concept of non-linear programming
3. Students should able to carry out sensitivity analysis
4. Student should able to model the real world problem and simulate it.

Syllabus Contents:

Module 1: Optimization Techniques, Model Formulation, models, General L.R Formulation, Simplex Techniques, Sensitivity Analysis, Inventory Control Models.

Module 2: Formulation of a LPP - Graphical solution revised simplex method - duality theory - dual simplex method - sensitivity analysis - parametric programming

Module 3: Nonlinear programming problem - Kuhn-Tucker conditions min cost flow problem - max flow problem - CPM/PERT

Module 4: Scheduling and sequencing - single server and multiple server models - deterministic inventory models - Probabilistic inventory control models - Geometric Programming.

Module 5: Competitive Models,Single and Multi-channel Problems, Sequencing Models, Dynamic Programming, Flow in Networks, Elementary Graph Theory, Game Theory Simulation.

Course Outcomes:

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

1. Students should able to apply the dynamic programming to solve problems of discreet and continuous variables.
2. Students should able to apply the concept of non-linear programming
3. Students should able to carry out sensitivity analysis
4. Student should able to model the real world problem and simulate it.

References:

1. H.A. Taha, Operations Research, An Introduction, PHI, 2008
2. H.M. Wagner, Principles of Operations Research, PHI, Delhi, 1982.
3. J.C. Pant, Introduction to Optimisation: Operations Research, Jain Brothers, Delhi, 2008
4. Hitler Libermann Operations Research: McGraw Hill Pub. 2009
5. Pannerselvam, Operations Research: Prentice Hall of India 2010
6. Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010.

Open Elective I : Cost Management of Engineering Projects (PM 2113)

Course Objective:

1. To provide appropriate knowledge, skills and techniques that would be used to maximise project outcomes and success. This will be useful for your final-year project proposal, and will include areas such as project life cycle, project management processes, project scope, time management, quality, and procurement.

Syllabus Content:

Module 1: Cost concepts in decision-making; Relevant cost, Differential cost, Incremental cost and Opportunity cost. Objectives of a Costing System; Inventory valuation; Creation of a Database for operational control; Provision of data for Decision-Making. Project: meaning, Different types, why to manage, cost overruns centres, various stages of project execution: conception to commissioning.
Module 2: Project execution as conglomeration of technical and nontechnical activities.Detailed Engineering activities. Pre project execution main clearances and documents Project team: Role of each member. Importance Project site: Data required with significance. Project contracts.Types and contents. Project execution Project cost control. Bar charts and Network diagram. Project commissioning: mechanical and process.

Module 3: Cost Behavior and Profit Planning Marginal Costing; Distinction between Marginal Costing and Absorption Costing; Break-even Analysis, Cost-Volume-Profit Analysis. Various decision-making problems. Standard Costing and Variance Analysis. Pricing strategies: Pareto Analysis. Target costing, Life Cycle Costing. Costing of service sector.Just-in-time approach, Material Requirement Planning, Enterprise Resource Planning,

Module 4: Total Quality Management and Theory of constraints.Activity-Based Cost Management, Bench Marking; Balanced Score Card and Value-Chain Analysis.Budgetary Control; Flexible Budgets; Performance budgets; Zero-based budgets. Measurement of Divisional profitability pricing decisions including transfer pricing.

Module 5: Quantitative techniques for cost management, Linear Programming, PERT/CPM, Transportation problems, Assignment problems, Simulation, Learning Curve Theory.

Course Outcomes:

1. On successful completion of this course, you should be able to:
2. understand and explain the nature of engineering projects
3. illustrate and understand how engineering project activities may be influenced by economic, environment, societal and organisational factors
4. access and evaluate information relevant to an engineering project
5. understand complex issues associated with engineering projects
6. understand ethical dimensions associated with conducting an engineering project

References:

1. Cost Accounting A Managerial Emphasis, Prentice Hall of India, New Delhi
2. Charles T. Horngren and George Foster, Advanced Management Accounting
3. Robert S Kaplan Anthony A. Alkinson, Management & Cost Accounting
4. Ashish K. Bhattacharya, Principles & Practices of Cost Accounting A. H. Wheeler publisher.
5. N.D. Vohra, Quantitative Techniques in Management, Tata McGraw Hill Book Co. Ltd.

Open Elective I: Composite Materials (PM 2114)

Course Objectives:

To understand the manufacturing processes of reinforcement fibers and matrices for composites and extend a knowledge of applications and selection of different composites in consideration of the properties and characteristics.

Syllabus Content:

Module 1: INTRODUCTION: Definition – Classification and characteristics of Composite materials. Advantages and application of composites.Functional requirements of reinforcement and matrix.Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

Module 2: REINFORCEMENTS: Preparation-layup, curing, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers. Properties and applications of whiskers, particle reinforcements. Mechanical Behavior of composites: Rule of mixtures, Inverse rule of mixtures. Isostrain and Isostress conditions.

Module 3: Manufacturing of Metal Matrix Composites: Casting – Solid State diffusion technique, Cladding – Hot isostaticpressing.Properties and applications. Manufacturing of Ceramic Matrix Composites: Liquid Metal Infiltration – Liquid phase sintering. Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving. Properties and applications.

Module 4: Manufacturing of Polymer Matrix Composites: Preparation of Moulding compounds and prepregs – hand layup method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding. Properties and applications.

Module 5: Strength: Laminar Failure Criteria-strength ratio, maximum stress criteria, maximum strain criteria, interacting failure criteria, hygrothermal failure. Laminate first play failure-insight strength; Laminate strength-ply discount truncated maximum strain criterion; strength design using caplet plots; stress concentrations.

Course Outcomes:

1. Understands the purpose and the ways to develop new materials upon proper combination of known materials
2. Is able to predict a wide range of mechanical and transport properties of materials as a function of parameters such as volume fraction, orientation & regularity arrangement and particle aspect ratio
3. Is capable of comparing/evaluating the relative merits of using alternatives (corresponding to various simple and composite materials) for important engineering and other applications.

Text books:

1. Material Science and Technology – Vol 13 – Composites by R.W.Cahn – VCH, West Germany.

2. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramaniam, John Wiley & Sons, NY, Indian edition, 2007.

References:

1. Hand Book of Composite Materials-ed-Lubin.
2. Composite Materials – K.K.Chawla.
3. Composite Materials Science and Applications – Deborah D.L. Chung.
4. Composite Materials Design and Applications – Danial Gay, Suong V. Hoa, and Stephen W. Tasi.

Open Elective I: Waste to Energy (PM 2115)

Course objectives:

1. To enable students to understand of the concept of Waste to Energy.
2. To link legal, technical and management principles for production of energy form waste.
3. To learn about the best available technologies for waste to energy.
4. To analyze of case studies for understanding success and failures.
5. To facilitate the students in developing skills in the decision making process

Syllabus Content:

Module 1: Introduction to Energy from Waste: Classification of waste as fuel – Agro based, Forest residue, Industrial waste - MSW – Conversion devices – Incinerators, gasifiers, digestors

Module 2: Biomass Pyrolysis: Pyrolysis – Types, slow fast – Manufacture of charcoal – Methods - Yields and application – Manufacture of pyrolytic oils and gases, yields and applications.

Module 3: Biomass Gasification: Gasifiers – Fixed bed system – Downdraft and updraft gasifiers – Fluidized bed gasifiers – Design, construction and operation – Gasifier burner arrangement for thermal heating – Gasifier engine arrangement and electrical power – Equilibrium and kinetic consideration in gasifier operation.

Module 4: Biomass Combustion: Biomass stoves – Improved chullahs, types, some exotic designs, Fixed bed combustors, Types, inclined grate combustors, Fluidized bed combustors, Design, construction and operation - Operation of all the above biomass combustors.

Module 5: Biogas: Properties of biogas (Calorific value and composition) - Biogas plant technology and status - Bio energy system - Design and constructional features - Biomass resources and their classification - Biomass conversion processes - Thermo chemical conversion - Direct combustion - biomass gasification - pyrolysis and liquefaction - biochemical conversion - anaerobic digestion - Types of biogas Plants – Applications - Alcohol production from biomass - Bio diesel production - Urban waste to energy conversion - Biomass energy programme in India.

Outcome of the course:

After completion of the course students should be able to-

1. Do sampling and characterization of solid waste; analysis of hazardous waste constituents including QA/QC issues; understand health and environmental issues related to solid waste management; apply steps in solid waste management-waste reduction at source, collection techniques, materials and resource recovery/recycling, transport, optimization of solid waste transport, treatment and disposal techniques; economics of the onsite vs. offsite waste management options
2. Evaluate the subject from the technical, legal and economical points by learning of all terms related to general solid waste management.
3. Set up a municipal solid waste management system.
4. Plan a solid waste management system for decision makers.

References:

1. Non Conventional Energy, Desai, Ashok V., Wiley Eastern Ltd., 1990.
2. Biogas Technology - A Practical Hand Book - Khandelwal, K. C. and Mahdi, S. S., Vol. I & II, Tata McGraw Hill Publishing Co. Ltd., 1983.
3. Food, Feed and Fuel from Biomass, Challal, D. S., IBH Publishing Co. Pvt. Ltd., 1991.
4. Biomass Conversion and Technology, C. Y. WereKo-Brobby and E. B. Hagan, John Wiley & Sons, 1996.