B.Tech. in Metallurgical and Materials Engineering

Scheme of Instruction and Examination

(Choice Based Credit System)

V Semester

S.No	Course Code	Course Title	Instruction: Hours Per Week L	T	P/D	Examination: Max. Marks CIE	SEE	Duration of SEE in Hours	Credits
			L	T	P/D	CIE	SEE	3	
1	MS502HS	Engineering Economics and Accountancy	3	0	0	30	70	3	**3**
2	MM501PC	Metal Casting	3	1	0	30	70	3	**4**
3	MM502PC	Mechanical Working of Metals	3	1	0	30	70	3	**4**
4	MM503PC	Steel Making	3	1	0	30	70	3	**4**
5		**Open Elective – I**	2	0	0	30	70	3	**2**
6	MC502ES	Cyber Security	3	0	0	30	70	3	**0**
7	MM551PC	Metal Casting Lab	0	0	3	30	70	3	**1.5**
8	MM552PC	Mechanical Working of Metals Lab	0	0	3	30	70	3	**1.5**
9	MM553PC	Metallurgical and Analytical chemistry Lab	0	0	2	30	70	3	**1.0**
10	MA554BS	**Finishing School – III (Quantitative Aptitude and Analytical Ability)**	0	0	2	30	70	3	**1.0**
		Total Hours/Marks/Credits	**17**	**3**	**10**	**300**	**700**		**22**

VI-Semester

S.No	Course Code	Course Title	Instruction: Hours Per Week L	T	P/D	Examination: Max. Marks CIE	SEE	Duration of SEE in Hours	Credits
			L	T	P/D	CIE	SEE	3	
1	MM601PC	Welding Metallurgy	3	1	0	30	70	3	**4**
2	MM602PC	Materials characterization	3	1	0	30	70	3	**4**
3	MM603PC	Powder Metallurgy	3	0	0	30	70	3	**3**
4		**Professional Elective – I**	3	0	0	30	70	3	**3**
5		**Professional Elective – II**	3	0	0	30	70	3	**3**
6		**Open Elective - II**	2	0	0	30	70	3	**2**
7	MC601HS	Intellectual Property Rights	3	0	0	30	70	3	**0**
	MC601ES	Artificial Intelligence	3	0	0	30	70	3	**0**
8	MM651PC	MetalJoining Lab	0	0	2	30	70	3	**1**
10	MM652PC	Metallurgical Computations Lab	0	0	2	30	70	3	**1**
11	EN653HS	**Finishing School – IV (Advanced communication skills lab)**	0	0	2	30	70	3	**1**
		Total Hours/Marks/Credits	**23**	**2**	**6**	**300**	**700**		**22**

9	MC601ESC	**Environmental Science (For Lateral Entry Students)**	**3**	**0**	**0**	**30**	**70**		**0**

L: Lecture T: Tutorial D:Drawing P:Practical

CIE: Continuous Internal Evaluation SEE: Semester End Examination

B.Tech. in Metallurgical and Materials Engineering

Scheme of Instruction and Examination

(Choice Based Credit System)

VII Semester

S.No	Course Code	Course Title	Instruction			Examination			Credits
			Hours Per Week			Max. Marks		Duration of SEE in Hours	
			L	T	P/D	CIE	SEE		
1	MT731ES	Introduction to Instrumentation	3	0	0	30	70	3	3
2	MM701PC	Corrosion Engineering of Materials	3	1	0	30	70	3	4
3		Professional Elective – III	3	0	0	30	70	3	3
4		Professional Elective – IV	3	0	0	30	70	3	3
5		Open Elective- III	2	0	0	30	70	3	2
6	MM751PC	Corrosion Engineering of Materials Lab	0	0	2	30	70	3	1
7	MM752PC	Modelling and Simulation Lab	0	0	2	30	70	3	1
8	MM753PC	Industry Oriented Mini Project*	0	0	2	0	100	3	1
9	MM754PC	Seminar	0	0	2	100	0	3	1
10	**Proj-I**	Project Stage – 1	0	0	6	30	70	3	2
		Total Hours/Marks/Credits	**14**	**1**	**14**	**340**	**660**		**21**

VIII-Semester

S.No	Course Code	Course Title	Instruction			Examination			Credits
			Hours Per Week			Max. Marks		Duration of SEE in Hours	
			L	T	P/D	CIE	SEE		
1	MS804HS	Industrial Management for Engineers	2	0	0	30	70	3	2
		Professional Elective – V	3	0	0	30	70	3	3
2		**Professional Elective – VI**	3	0	0	30	70	3	3
4	Proj- 2	Project Stage– 2	0	0	16	30	70	3	8
		Total Hours/Marks/Credits	**8**	**0**	**16**	**120**	**280**		**16**

L: Lecture **T: Tutorial** **D:Drawing** **P:Practical**
CIE: Continuous Internal Evaluation **SEE: Semester End Examination**

Mahatma Gandhi Institute of Technology
B.Tech. in Metallurgical and Materials Engineering

Scheme of Instruction and Examination

<u>List of Professional Electives</u>

Professional Elective – I

MM611PE	Introduction to Numerical Analysis
MM612PE	Nanomaterials
MM613PE	Alloy Steels

Professional Elective – II

MM614PE	Non-Metallic Materials
MM615PE	Advancesin Surface Engineering
MM616PE	Fracture Mechanics and Failure Analysis

Professional Elective – III

MM711PE	Material Data Science and Informatics
MM712PE	Additive Manufacturing of Materials
MM713PE	Advanced Manufacturing Techniques

Professional Elective – IV

MM714PE	Transport Phenomena in Materials Engineering
MM715PE	Light Metals and Alloys
MM716PE	Ceramic Science and Technology

Professional Elective – V

MM811PE	Artificial Intelligence in Materials Engineering
MM812PE	Advanced Materials
MM813PE	Non-Destructive Evaluation

Professional Elective – VI

MM814PE	Design and Selection of Materials for high temperature Applications
MM815PE	Materials for Automotive Applications
MM816PE	Composite Materials

<u>List of Open Electives offered by MMT to other Branches</u>

Open Elective – I

MM521OE	Testing of Materials
MM522OE	Metallurgy for Non-Metallurgists

Open Elective - II

MM621OE	Design and Selection of Materials
MM622OE	Engineering Materials

Open Elective- III

MM721OE	Light Metal Technology
MM722OE	Surface Engineering

L	T	P	C
3	1	0	4

B.Tech in Metallurgical and Materials Engineering
V Semester Syllabus
MM501PC: Metal Casting

Course Objectives

- This course is mainly intended to introduce and explain various moulding, casting techniques and equipment used
- This course is mainly intended to introduce and explain various moulding, casting equipment used
- Principles of Solidification of castings
- Defects in castings and their remedies are also dealt in detail

Course Outcomes

This course paved a platform for students to develop a thorough understanding on the,

- Casting technologies,
- Different Moulding process
- Solidification of metals and alloys
- Cupola, Induction furnace
- Identified the casting Defects and found the suitable remedies

Unit - I: Introduction to Foundry –Types of Foundries and Patterns

Materials for patterns, types of patterns, properties of pattern materials; functions and pattern allowance. Cores, core prints and core making, Moulding materials; moulding sands, properties and selection of binding materials and additives.

Moulding Processes: Green and dry sand moulding; shell moulding, CO_2 moulding, Plaster moulding, Investment casting

Unit - II: Casting Methods

Permanent and Expendable moulding, pressure die-casting, Gravity die casting, Vacuum die casting, Horizontal, Vertical and Semi centrifugal casting, Squeeze casting and Composite Casting

Unit - III: Melting and Solidification

Solidification, Nucleation, and growth. Freezing of metals and alloys. Dendritic freezing. Progressive and Directional Solidification. Gating, Risering and their design

Unit - IV: Modern Developments

Recently developed processes-V-Forming Full Mould Process, Furon-No-Bake Sand Moulds and Cores, Cold Setting, and Self Setting Processes. Cupola furnace, construction of cupola furnace, Melting of Gray Iron in cupolaand Induction furnace Melting,

Unit - V: Casting Defects and Remedial Measures

Casting defects arising due to moulding, cores, melting and pouring practice. Various NDT Inspection and Testing of castings

Suggested Readings:

1. Principles of Metal casting by Heine – Loper and Rosenthal, Tata Mc Graw Hill, 2nd Edition.
2. Metal Casting : Principles and practice – T.V. Ramana Rao, New Age, International, 2007

Reference Books:

1. Foundry Technology – Dharmendra Kumar &S.K.Jain, CBS Publisher, 2007
2. Fundamentals of metals casting, P. C. Mukherjee, Oxford & IBH Pub. Co., 1988
3. Casting Technology and Cast Alloys – AK Chakrabarti – PHI 2011 Edition
4. Castings – John Campbell – Second Edition – Elsevier
5. Metal Casting: Principles and practice – T.V. Ramana Rao, New Age, International, 2007.

L	T	P	C
3	1	0	4

B.Tech in Metallurgical and Materials Engineering
V Semester Syllabus
MM502PC: Mechanical Working of Metals

Course Objectives

- To introduce students to the consequences of the application of loads on metals
- To analyse stress and strain at an inclined plane from the given three-dimensional stresses.
- To impart knowledge about principles and criteria of yielding during forming of metals
- To impart knowledge on analysis of different bulk metal forming processes.
- To understand the role of different controlling process parameters in metal forming processes

Course Outcomes

- To choose the best forming process for a specific product.
- Use the Mohr's circle to graphically analyse stresses.
- Analyze, compare, and finally gain theoretical experience for the advantages and limitations of different manufacturing processes
- To practically appreciate the utilization of these fundamentals in industrial manufacturing processes.
- To analyse metallurgical and mechanical aspects of forming of metals into useful shapes and properties.

Unit - I: Stress-Strain Relationship-Elastic Behavior

Concept of stress and types of stresses. Resolution of total stress into its components. Concept of strain and types of strains. Description of stress at a point Plane stress, State of stress in two dimensions: Construction of Mohr's circle of stress for two-dimensional state of stress. State of stress in three dimensions: Construction of Mohr's circle of stress for three-dimensional state of stress. Description of strain at point. Hydrostatic and Deviator components of stress. Elastic stress strain relations. Calculation of stresses from elastic strains. Plane strain. Strain energy.

Unit - II: Elements of Theory of Plasticity

Basics of the theories of plasticity. The flow curve. Idealized flow curves. True stress and true strain. Relationship between engineering stress and true stress, engineering strain and true strain. Constancy of volume relationship. Advantage for true strain in metal working. Yielding criteria for ductile metals. Von Mises distortion energy criterion Maximum shear stress or Tresca criterion. The yield locus. Octahedral shear stress and shear strain. Plastic stress strain relations, Levy- Mises equations.

Unit - III: Fundamentals of Metal Working

Classification of forming processes: High energy rate forming process, Explosive forming. Mechanics of metal working: slab method and uniform deformation energy method Flow stress determination, Plane strain compression test. Mean flow stress, Cold working, Recovery, recrystallisation and grain growth, Hot working Strain-Rate effects Work of plastic deformation. Stresses acting on an element during drawing of a wide sheet. Dynamic recovery and Dynamic recrystallisation. Friction and lubrication. Deformation zone geometry. Hydrostatic pressure.

Unit - IV: Forging and Rolling of Metals

Forging: Classification of forging processes: Open-die, closed-die, impression die and isothermal forging. Forging operations: Swaging, fullering, edging, cogging, coining, drawing out, upsetting. Forging equipment. Forging of a rectangular slab in plane strain, Forging of a cylinder in plane-strain, Forging defects. Rolling of Metals: Classification of rolling process, rolling mills, Classification of rolling mills, Hot rolling, cold rolling, Rolling of bars and shapes, Geometrical relationships in rolling, Simplified analysis of rolling load, rolling variables. Front tension and back tension, effect of strip tension on distribution of roll pressure, Rolling mill control. Problems and defects in rolled products. Theories of cold and hot rolling, torque and horsepower

Unit - V: Extrusion and Drawing

Extrusion: Classification of extrusion processes-Direct extrusion, Indirect extrusion, Hydrostatic extrusion, and Impact extrusion. Extrusion equipment. Typical extrusion dies- Flat and conical dies. Patterns of metal flow in extrusion. Hot extrusion Deformation and defects in extrusion. Analysis of the extrusion process Cold extrusion of tubing and production of seamless pipe and tubing, Spider dies, Mannesmann mill process. Drawing of Rods, Wires and Tube: rod, wire, and tube drawing processes. Drawing die. Analysis of wire drawing, Analysis of tube drawing. Maximum possible reduction in drawing, Defects in drawing, Residual stresses in rod, wire and tubes. Deep drawing of sheets.

Suggested Readings:

1. Mechanical Metallurgy by GE Dieter (3rd edition)
2. Metal forming mechanics of metallurgy, William F.Hosford, Robert M.Caddell. Cambridge, 3rd Edition.
3. Technology of Metal Forming Processes – Surender Kumar PHI 2008

Reference Books:

1. Mechanical Working of Metals - Avitzur.
2. Mechanical Properties and Working of Metals and Alloys, Amit Bhaduri, Springer

L	T	P	C
3	1	0	4

B.Tech in Metallurgical and Materials Engineering
V Semester Syllabus
MM503PC: Steel Making

Course Objectives

This course is primarily of industrial oriented and designed to make the student to understand and demonstrate the

- Various types of primary steel making processes
- Hot metal route and scrap route, casting pit side practice,
- Continuous casting of steel and
- secondary steel making process to produce quality steels

Course Outcomes

The student would gain knowledge on different

- To know the Primary steel making processes.
- To know the importance of Secondary Steel making processes
- To get the knowledge of producing quality steels with less cost
- To improve the efficiency of Steel making

Unit - I: Introduction to Steel Making

Current scenario of steel making in India and world, Raw materials of steel making. Factors affecting the efficiency of steel making. **Principles of Steel making**; Removal of Carbon, Silicon, Manganese, phosphorous and sulphur. Role of slag, types, and properties of slags. Molecular and ionic theory of slags. Principles of deoxidation. Precipitation and diffusion deoxidation.

Unit - II: Primary Steel Making (Hot Metal)

Steel making by Acid and Basic Bessemer Processes, Construction and lining details, sequence of elimination of impurities, Steel Making by LD process, Construction, lining and process details in LD, LD-AC or OLP, Kaldo, LD-Kaldo, Rotor oxygen steel making, Oxygen bottom blowing (OBM), Hybrid process of steel making, Improvements and modification of the above steel making process.

Unit - III: Primary Steel Making (From Scrap)

Open Hearth Steel Making: Construction and process details; Electric Arc Furnace (EAF); Construction and Process details: Induction furnace. Stainless steel making.

Unit - IV: Secondary Steel Making

Secondary steel making processes. Electro Slag Remelting (ESR), Vacuum Arc Remelting (VAR). Brief outline of manufacture of alloy steels. Vacuum treatment of steels. AOD, VOD, Synthetic slag treatments, De-carburization techniques de-gassing of steel Powder injection etc. methods

Unit - V: Solidification of steels.

Ingot defects and remedies; Casting pit side practice: Types of Moulds, Teeming Methods, Killed, Semi Killed, capped and rimmed Steels, Continuous casting of steels.

Suggested Readings:

1. Steel Making – V. Kudrin
2. Modern Steelmaking – Dr. R.H. Tupkary and V.H. Tupkary
3. Steel Making – A. K. Chakravarthy (PHI) 2007

Reference Books:

1. Iron Making & Steel Making Theory and Practice - Ahindra Ghosh & Amit Chatterjee
2. Secondary Steel Making; Principles and applications – Ahindra Ghosh
3. Physical Chemistry of Iron & Steel by Bodsworth.

L	T	P	C
0	0	3	1.5

B.Tech in Metallurgical and Materials Engineering
V Semester Syllabus
MM551PC: Metal Casting Lab

Course Objectives

- This Laboratory course is designed to make the student to understand and demonstrate
- This lab course is mainly designed to provide hands on practice on the various foundry testing methods for evaluation of moulding sand properties

Course Outcomes

Upon successful completion of this course, the student will be able to:

- Determine moulding sand dry, hot and green strength
- Understand the preparation of moulding sand
- Determine moulding sand properties by varying additives
- Understand the Melting of Al alloys

List of Experiments:

1. Preparation of gating system using green moulding sand.
2. Study of particle size distribution of the sand.
3. Study of the variation of permeability of the green sand with clay and water.
4. Determination of the variation of sand properties like green hardness, green compact strength with additives in sands.
5. Determination of the variation of hot compact hardness and hot shear strength with additivesin sands.
6. Determination of clay content in sand.
7. Determination of the shatter index of green sand.
8. Melting of Al alloys in a pit furnace and casting into light components.
9. Study of Charge calculations and melting practice of cast iron in cupola.
10. Preparation of a shell-by-shell moulding process.
11. Study of Non-destructive testing of few components.

Equipment:

1. Mould Boxes, Patterns, Core Boxes, Tool Boxes.
2. Rotap Sieve Shaker with Sieves
3. Permeability Apparatus.
4. Universal Sand Testing Machine with Accessories.
5. Sand Hardness tester.
6. Clay Content Apparatus
7. Shatter Index test.
8. For Melting; Pit Furnace; Electric Furnace
9. Shell Moulding Machine
10. Centrifugal Casting Machine
11. Ultra Sonic Tester
12. Ladles, Crucibles and other Accessories
13. Muffle Furnace 1000^0c

L	T	P	C
0	0	3	1.5

B.Tech in Metallurgical and Materials Engineering
V Semester Syllabus
MM552PC: Mechanical Working of Metals Lab

Course Objectives

- This lab course is designed to know the various testing methods for evaluation of metal forming techniques.

Course outcomes

Upon successful completion of this course, the student will be able to

- Determine strain hardening exponent from the stress-strain diagram.
- Understand the difference between simple, progressive and compound dies.
- Understand the effect of cold working and annealing on microstructure.
- Illustrate the effect of friction and semi die –angle on metal flow in extrusion.
- Practice various deformation processes like extrusion, deep drawing and redrawing

List of Experiments:

1. To determine the formability of given materials by Erichson cup test
2. To manufacture washer components using fly press (progressive dies /compound dies)
3. Deep drawing of a cup with / without blank holder by hydraulic press
4. Redrawing of a cup with / without blank holder by hydraulic press
5. To determine the friction factor by ring compression test
6. Determination of strain hardening exponent 'n' and strength coefficient 'k'
7. To verify Hall-Petch relation in MS specimen.
8. To determine the effects of cold working on the microstructure and mechanical properties of given metal.
9. To demonstrate the effect of friction and height-to-diameter ratio in the axi-
10. Symmetric compression of a cylinder to analyze the metal flow in extrusion with different friction conditions and semi- die angles.

List of Equipment:

1. UTM, 2. Hydraulic press, 3. Fly press, 4. Erichson cup Tester

L	T	P	C
0	0	2	1

B.Tech in Metallurgical and Materials Engineering
V Semester Syllabus
MM553PC: Metallurgical and Analytical Chemistry Lab

Course objectives

- This course introduces chemical analysis of metallic alloys using laboratory practice

Course Outcomes

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

- Identify the major elements in a metallic alloy using chemical methods
- Quantify specific elements in ferrous and non-ferrous alloys using titration
- Interpret the results from different spectroscopy instruments to determine chemical composition
- Application of Electrochemical principles
- To understand the concepts of calorific values of different fuels

List of experiments:

1. Preparation of standard solutions and standardization of standard solutions.
2. Estimation of Iron in Iron ore by KMnO4 and $K_2Cr_2O_7$ methods.
3. Determination of Silicon in steel by gravimetric method.
4. Estimation of Manganese in Ferro-alloys by spectrophotometer.
5. Estimation of Sodium and Potassium in Chloride Salts by Flame Photometry.
6. Estimation of Copper in Brass by Electrochemical Analyzer.
7. Determination of Carbon and Sulphur in Ferrous Materials by "Stroheleins Apparatus"
8. Determination of viscosity of a given fluid by Viscometers (Redwood -I, Redwood – II and Saybolt viscometer).
9. Determination of calorific value of Solid and liquid fuels.

List of Equipment:

1. Flame Photometer 2. Spectrophotometer. 3. Electrochemical Analyzer.
4. Colorimeters. 5. Bomb Calorimeter 6. Chemicals and Glassware.
7. Junker's gas calorimeter, 8. Redwood and Saybolt viscometers.

Suggested Readings:

1. A textbook of metallurgical analysis, B C Aggarwal, Khanna Publishers (2002)
2. Wilfred W. Scott ; Standard methods of Chemical Analysis

Reference Books:

1. Instrumental methods of analysis, Willard, CBS Publishers & Distributors (2004)
2. Young R.S.; Chemical Analysis in Extractive Metallurgy; Charles, Griffin & Co. Ltd, 1971

L	T	P	C
3	1	0	4

B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
MM601PC: Welding Metallurgy

Course Objectives:

- To impart knowledge on various welding processes so that the students can apply them in engineering industry applications.
- Gain knowledge of the concepts, operating procedures, applications, advantages and limitations of various welding processes
- knowledge about the thermal and residual stresses associated with welding processes
- Gain knowledge of process, difficulties, and microstructures formed during welding of high carbon steels, cast irons, Stainless steels and Aluminum alloys and the remedial measures to minimize or eliminate the occurrence of weld defects
- To develop the knowledge on the the quality control of weldments.

Course Outcomes:

- Understand the basics of various metal joining processes
- Describe the development of the fusion and heat-affected zones during welding and how the weld variables and weld Microstructure affect the mechanical properties of the weld
- Correlate the solidification behavior and structure of weld zone with the welding parameters
- Understand the metallurgical compatibility in joining dissimilar metals and apply the suitable methods.
- Apply remedial measures to minimize defects in welding of stainless steels, Al alloys, Cu alloys based on proper understanding of the processes used and microstructural study of weld joints.

Unit - I: Welding Processes

Introduction to the process of welding Advantages Disadvantages and applications of welding
Classification of welding processes: Fusion vs Non fusion, Pressure Vs Non-Pressure, Fusion welding processes by energy source. Welding arc, arc plasma, Volt-Ampere characteristics for welding
Principles, advantages disadvantages and fields of application of the following welding processes: Gas Welding, MMAW, GTAW, GMAW, SAW, ESW & EGW
Resistance Welding: Principles, advantages disadvantages and fields of application of the following welding processes: Resistance spot welding, Resistance seam welding, Projection welding, Flash welding, Upset welding
Other metal joining techniques: Principle of Adhesive bonding, classification of adhesives Advantages disadvantages and applications of Adhesive bonding.
Brazing: Principle, Common brazing techniques Torch brazing, Induction Brazing, Vacuum Brazing and Furnace brazing. Advantages Disadvantages and Applications of Brazing.

Soldering: Principle, Advantages Disadvantages and applications. Soldering tools, Types of solders and Soldering Techniques.

Unit - II: Solid-State welding and Advanced Metal Joining Techniques

Working principle. Advantages limitations and applications of the following solid state welding processes.

Friction: Linear friction, Rotary friction: continuous drive and inertia friction welding.

Friction stir: Process variables tool rotational speed, traverse speed and plunge depth.

Explosive welding: Types of explosives, cladder placement-parallel and angled.

Diffusion welding and ultrasonic welding.

Advanced Metal Joining Techniques: Plasma Arc Welding: Energy density in plasma, Keyhole mode, Transferred and Non-Transferred arc Working principle. Advantages limitations and applications

Unit - III: Weldability concepts of ferrous and non-ferrous alloys

Weldability, Microstructure of fusion zone and heat affected zone in cold worked metals, precipitation.Metal transfer in non-consumable arc welding hardenable alloys, Transformation hardenable alloys

Heat input, effect of heat input on microstructure and mechanical properties. Effects on preheat and cooling rate.Importance of PWHT

Thermal and residual stresses: Origin of thermal stresses, Distortion Vs Residual stresses, Causes of residual stresses in weldments, residual stress effects, reduction and control

Weldability of high carbon steel, cast irons, stainless steels. Importance of Schaffler and Delong diagrams.

Welding of non-ferrous alloys - Properties of Aluminum alloys:Typical welding problems in Aluminum alloys, weldability of Al-Cu alloy. Cu-base alloys and weldability of phosphorous-deoxidised copper, Aluminum bronze and cupronickel alloys.

Unit - IV: Dissimilar metal welding and Joining of Ceramics

Welding of dissimilar metals: Importance and applications of dissimilar metal welding, Challenges in welding of dissimilar metals, metallurgical compatibility, Heating process during dissimilar joining, weld dilution in dissimilar metal welding, interlayers in dissimilar metal welding,Buttering Technique. Examples of dissimilar metal welding: Welding Aluminum to steel, Copper to steel, P91 to AISI 304.

Joining of ceramics: Properties of ceramics, Problems in joining ceramics, Metal/ceramic joining techniques-Active metal Brazing, Metallization, solid state diffusion with case studies.

Unit - V: Defects and Quality testing of weldments

Defects in weldments-Misalignment, porosity, Reinforcement, crater, slag inclusions, spatter, under bead crack, incomplete penetration, Burn-Through, overlap, their causes, effects and remedies. Weld decay /sensitization and knife line attack in Austenitic stainless steel, stress corrosion cracking, causes, effects, and remedial measures. Hot cracking and cold cracking causes and remedies. Introduction to quality testing of weldments: Principle of dye penetrant test and Radiography. Quality testing of weldments using dye penetrant and Radiography.

Suggested Readings:

1. Principles of welding, Robert W. Messler,Jr. Wiley-VCH
2. Metallurgy of Welding,J.F.Lancaster
3. Parmer. R. S. “Welding Engineering and Technology”, Khanna Publications

Reference Books:

1. R.S. Parmer: Welding Processes and Technology, Khanna Publishers
2. G. den Ouden M.J.M. Hermans,VSSD
3. Nadkarni S.V., “Modern Arc Welding Technology”, Oxford IBH Publishers

L	T	P	C
3	1	0	4

B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
MM602PC: Materials Characterization

Course Objectives:

- To obtain knowledge on various structural and microstructural characterization techniques of materials.
- To study the principles, theory and practice of various characterization techniques.
- The latest advancement in microscopy for getting structural and elemental analysis of materials.

Course Outcomes:

- To analyze microstructure of the materials by operating Optical Microscope and, also, quantitative metallography.
- To make out the basic operational modes of a Scanning Electron Microscope.
- To identify the basic operational modes of a Transmission Electron Microscope and the diffraction patterns.
- To comprehend the production of x-rays and the principles of diffraction (Bragg's Law).
- To realize the applications of X-ray diffraction - Determinations of Crystal Structure, Precise Parameter, Phase Diagram, Order-Disorder Transformation and Residual Stress.

Unit - I: Optical Microscopy

Optical Principle – Image formation, Resolution, Numerical aperture, Magnification, Components of Optical microscope, Illumination System – Electric Lamps of Optical microscope, Important lens defects and their corrections, Specimen Preparation – Sectioning, Mounting, Grinding and Polishing and Etching, Imaging Modes – Bright and Dark Field, Principle of Phase Contrast, Polarized light microscopy, Differential Interference Contrast and Confocal Microscopy, Elements of quantitative Metallography.

Unit - II: Principle – Construction and Working principles SEM, Electron Sources – Thermionic Emission Gun and Field Emission Gun, Electromagnetic Lenses, Working Distance, Depth of field, Depth of focus, Signal Detection, Contrast Formation - Interaction of electron beams with matter, Topographic Contrast, and Compositional Contrast, Different types of modes used in SEM (SE and BSE) and their applications, Specimen preparation for SEM, Advantages, limitations, and applications of SEM.

Unit - III: Transmission Electron Microscopy

Principle – Construction and Working principle of TEM, Resolving power and Magnification, Depth of field and Depth of focus Image, Specimen Stage, Specimen preparation for the TEM – Pre-Thinning, and Final Thinning – Electrolytic Thinning, Ion Milling, and Ultramicrotomy, Modes: Bright and Dark field, Mass – Density Contrast and Diffraction Contrast – Selected Area Diffraction, Applications of TEM, Advantage and Limitations of TEM.

Unit - IV: X - Ray Diffraction

Introduction of X-rays, Production – Filament tube method and properties of x-rays – Continuous and Characteristic Spectrum, Bragg's law of diffraction, Diffraction under non-ideal conditions, Experimental Methods of Diffraction – Transmission and Back-Reflection Laue method, Powder method, Diffractometer, Intensity of Diffracted beams – Scattering by an electron, by an atom, by a unit cell, Structure-factor calculations – Simplest unit cell, Base, Body and Face-Centered and Hexagonal unit cells, Examples of NaCl, Factors affecting Diffraction Intensities – Multiplicity and Absorption factors, Temperature factor, Lorentz factor.

Unit - V: Application of XRD

Orientation of single crystals – Schultz methods, Effect of plastic deformation; The structure of Polycrystalline Aggregates-Crystal size: Grain size and Particle size, Crystal Perfection: Quality, Crystal Orientations: Texture of Wire and Sheet, Determination of crystal structure – Indexing pattern of Cubic and Non-Cubic crystals, Determination of No. of Atoms in a unit cell and Atom Position, Precise lattice parameter measurements - Cubic and Non-Cubic crystals, Stress measurement: Principle and Experimental Technique: Diffractometer, Order-disorder transformation – Long range ordering in $AuCu_3$, Au-Cu.

Suggested Readings:

1. Material Characterization: Introduction to Microscopic and Spectroscopic Methods – Yang Leng – John Wiley and Sons (Asia) Pvt. Ltd. 2008
2. Elements of X-ray diffraction – Bernard Dennis Cullity and Stuart R Stocks, Prentice Hall, 2001 – Science
3. Materials Characterization (Vol. 10), George M. Crankovic, Kathleen Mills, Ruth E. Whan, ASM Handbook Committee

Reference Books:

1. Microstructural Characterization of Materials – David Brandon, Wayne D Kalpan, John Wiley and Sons Ltd., 2008.
2. The Principles of Metallographic Laboratory and Practices (Metallurgy) – George L. Khel- McGraw-Hill, 1949.
3. Experimental Techniques in Materials and Mechanics – C. Suryanarayana, CRC Press, Taylor & Francis Group, 2011.
4. Metallography: Principles and Practices – George F. Vander Voort, ASM International, 1984 – Technology and Engineering
5. X-ray diffraction: A Practical Approach – C. Suryanarayana and M Grant Norton, Springer Science Business Media, LLC, 1998.

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B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
MM603PC: Powder Metallurgy

Course Objectives:

- This course is designed to impart various principles of metal powder processing applied to fabrication of structural and commercial products.
- It is also intended to elucidate the process variables in powder metallurgy technology and develop concepts of intellectual thinking for future applications

Course Outcomes:

At the conclusion of the course, the student will be able to have thorough understanding on

- Powder Manufacturing techniques
- Powder characterization
- Powder consolidation
- Major applications of P/M

Unit - I: Introduction.

Importance and emergence of powder metallurgy Metal powder technology, comparison of powder metallurgy with other manufacturing techniques. Merits, limitations, and applications.
Powder Productionmethods: chemical reduction (tungsten, iron), carbonyl decomposition (iron, nickel), atomization (pure metal and multicomponent alloy powders), milling (oxides), and electrolysis (elemental powders).

Unit - II: Powder Characterization

Determining powder characteristics: particle shape, size, size distribution (Sieve analysis, Fisher Sub sieve), specific surface area, apparent and tap density (Hall Flow meter), angle of repose, compressibility/compactibility. Influence of the manufacturing process on powder characteristics.

Unit - III: Consolidation of Metal Powders: Compaction:

Introduction and importance of Compaction**,** Die compaction, Single die and double die compaction. Theory of compaction: Pressure transmission in powders. Pressure dependence of densification. Green strength, Green Density.

Unit - IV: Consolidation of Metal Powders: Sintering:

Introduction to Sintering, Mechanisms of solid state and liquid phase sintering. Effect of powder characteristics on compaction and sintering. Hot Pressing, Sinter forging. Properties of P/M parts:mechanical properties (UTS, YS and ductility) and Physical properties (thermal and electrical conductivity, density).Principles of Spark Plasma sintering.

Unit - V: Powder Metallurgy Products:

i. **Porous Parts**: Filters, Self-lubricating bearings (CuSn).
ii. **Dispersion strengthened materials**: (Al_2O_3,Ni-ThO_2).
iii. **Electrical materials** - Tungsten lamp filaments, Thoriated tungsten welding electrodes, tungsten automobile electrical contacts
iv. **Magnetic materials**: Fe-Ni soft magnets, ALNICO and $SmCo_5$ permanent magnets.
v. **Cutting Tools**: Cemented carbides (WC-Co). VI. Special Products: Heavy alloys (W-Ni-Fe).

Suggested Readings:

1. Powder metallurgy – Anil Kumar Sinha, Dhanpat Rai & Sons, NaiSarak, 110006, 1981

Reference Books:

1. Powder Metallurgy Science- Randall M German , Metal Powder Industries Federation, 1994 - Technology & Engineering ,USA,1994
2. Powder Metallurgy Science, Technology and Materials, Anish Upadhaya, GS Upadhaya, University Press, IIM, 2011
3. Introduction to powder metallurgy – J.S. HirshhornAmerican ***Powder Metallurgy*** Institute, Princeton NJ, 1969
4. Treatise on Powder metallurgy – Claus Guenther Goetzel Vol 1& II Interscience Publishers, 1950
5. Powder Metallurgy principles – Fritz V. Lenel , Princeton, 1986
6. ASM Handbook on Powder Metallurgy, Metals Park, Ohio, USA

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B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
Professional Elective –I
MM611PE: Introduction to Numerical Analysis

Course objectives

- This course introduces numerical analysis, which is the backbone of Computational Materials Engineering

Course Outcomes

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

- Understand interpolation and curve fitting
- Understand numerical differentiation and integration
- Solve algebraic and transcendental equations
- Find roots of polynomial equations
- Find Eigen values and Eigen vectors

Unit - I

Approximations and errors in computation, finite differences-divided differences, Newton-Gregory forward and backward interpolation formulae, Newtons divided difference interpolation, Lagrange's interpolation, inverse interpolation, curve fitting by the method of least squares, linear and quadratic curve fitting.

Unit - II

Numerical differentiation and numerical integration, trapezoidal and Simpsons rules, numerical double integration. Numerical solution of initial value problems in ordinary differential equations by Taylors series method, modified Eulers method, Runge-Kutta methods of second and fourth orders, predictor-corrector method, Adams Bashforth and Adams Moultan methods.

Unit - III

Numerical solution of algebraic and transcendental equations, rate of convergence and condition of convergence, Methods of ordinary iteration, Regula-falsi and Newton-Raphson methods

Unit - IV

Multiple roots of polynomial equations by generalized Newtons method, Solution of systems of linear equations by Newton-Raphson method. Solution of systems of linear equations, Gauss-Jacobi, Gauss-Seidel and relaxation methods

Unit – V

Eigenvalues and eigenvectors, finding the largest eigen value by power method. Solving difference equations with constant coefficients

Suggested Readings:

1. Richard L. Burden and J. Douglas Faires, Numerical Analysis - Theory and Applications, Cengage Learning, Singapore.
2. S.S. Sastry, Introductory Methods of Numerical Analysis, Fourth Edition, Prentice-Hall, India.

Reference Books:

1. David Kincaid and Ward Cheney, Numerical Analysis - Mathematics of Scientific Computing, American Mathematical Society, Providence, Rhode Island.
2. Kendall E. Atkinson, An Introduction to Numerical Analysis, Wiley India.

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B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
Professional Elective I
MM612PE: Nanomaterials

Course objectives

- This course is primarily intended to expose the students to a highly interdisciplinarysubject.
- This would emphasize on the classification, synthesis and applications of Nanomaterials.

Course outcomes

After completing this course, the student should be able to:

- Indicate the differences between nanomaterials and conventional materials
- Indicate how specific synthesis techniques can result in nanomaterials
- Give examples of specific nanomaterials and explain the scientific reasons for the properties displayed by them
- Describe how specific characterization techniques can be used to analyze nanomaterials

Unit – I: Introduction

Importance of Nanotechnology, Emergence of Nanotechnology, Bottom-up and Top- down approaches, merits, challenges and applications of Nanotechnology. Important classes of Nanomaterials, description with appropriate examples. Significant characterization methods involved for these Nanomaterials.

Unit – II: Zero dimensional nanostructures

Nanoparticles-synthesis through homogenous nucleation; growth of nuclei, Fundamentals of heterogeneous nucleation, synthesis of metallic Nanoparticles through heterogeneous nucleation, synthesis of nanoparticles using micro emulsions and Aerosol.

Unit – III: One dimensional nanostructures

Nanowires and nanorods, Spontaneous growth: Evaporation and condensation growth, vapor-liquid-solid growth, stress induced recrystallization. Template based synthesis: Electrochemical deposition, Electro-phoretic deposition. Electro-spinning and Lithography.

Unit – IV: Two dimensional nanostructures

Fundamentals of film growth. Physical vapour Deposition (PVD), Chemical Vapour Deposition (CVD), Typical chemical reactions, Reaction kinetics, transport phenomena involved in CVD methods, deposition of diamond films by CVD. Evaporation molecular beam epitaxy (MBE), Sputtering, Comparison of Evaporation and sputtering. Thin films, Atomic layer deposition (ALD), Electrochemical deposition (ECD), Sol-Gel films.

Unit – V: Three dimensional nanostructures

Nanocomposite materials, synthesis, characterization, and applications. Special Nano Materials, Carbon fullerene and nano tubes: carbon fullerenes, formation, properties, and applications. Carbon nano tubes: formation and applications.

Suggested Readings:

1. Nano structures and Nano materials: Synthesis, properties and applications - Guozhong Cao- Imperial College press in 2004, 2nd edition.
2. Textbook of Nano Science and Technology, B S Murthy, Universities press-IIM series in Metallurgy and Material Science

Reference Books:

1. Springer Handbook ofNanotechnology
2. Nano Materials Synthesis, Properties and applications, 1996 Edlstein and Cammarate.
3. Nano Materials A.K. Bandhopadyay/ New agePublications
4. Nano Essentials T Pradeep /TMH

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B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
Professional Elective – I
MM613PE: Alloy Steels

Course Objective

Understand the basic concepts of advanced steels

Course Outcome

- Understand the structure and properties automotive applications
- Understand the properties and applications of stainless steels
- Understand the processing, properties, and application of Maraging steels
- Know the Steels used in fossil fired power plants, pipes and railways
- Know the steels used in Fission and Fusion power plant

Unit - I

Steels for Automobile applications, comparative study of interstitial free, dual phasesteels , HSLAsteels, TRIP steels, TWIP steels, ŕ-values, bainitic steels and heat treatments

Unit - II

Composition properties and application of stainless steels, ferritic martensitic, austenitic steels, semi austenitic steels, precipitation hardening steels, duplex steels

Unit - III

Maraging steels, composition, heat treatment, melting, fabrication, and applications

Unit - IV

Steels for fossil fired power plants, oil and gas industries, long products, railways

Unit - V

Steels for nuclear fission reactors: Temperature and Pressure requirements, Low alloy ferritic steels, Austenitic stainless steels, role of alloying elements, Radiation damage, Steels for nuclear fusion reactor: Alloying elements and Activation, RAFM steels, ODS steel, irradiation embrittlement

Suggested Readings:

1. Physical Metallurgy and Designing of Steels, F B Pickering
2. The Physical Metallurgy of Steels, W C Leslie
3. Steels: Metallurgy and Applications – D.J. Llewellyn and R.C. Hudd

Reference Books:

1. Physical Metallurgy of Metals & Alloys - Bricks & Philips

2. Making Shaping and Treating of Steel Vol.- II "Steel Making and Refining Process" - U. S. Steel Co.
3. Fundamentals of Radiation Materials Science, Gary S. Was

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B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
Professional Elective – II

MM614PE: Non-Metallic Materials

Course objectives

- To introduce the student to the range of non-metallic materials available for engineering.
- To understand the classification and significance of nonmetallic materials to apply them in Industries
- To get an exposure to the techniques associated with the synthesis, processing and characterization of these materials and
- To become aware of the applications where these materials are preferred

Course outcomes

After completing this course the student can:

- List the prominent non-metallic materials available for engineering applications
- Indicate the uses for which these materials are preferred
- Indicate the structure property relations in these materials
- Indicate the synthesis and processing steps associated with these materials

Unit - I: Non-metals of periodic table

Introduction, structure and properties, advance applications (aerospace, automobile, fuels, electronics, pesticides, household appliances, etc.,):Hydrogen, Carbon Nitrogen, Oxygen, Fluorine, Phosphorus, Sulfur, Chlorine, Bromine, Astatine, Helium, Neon, Argon, Boron, Silicon, Germanium, Arsenic, Antimony, Tellurium.

Unit - II: Fibers

Definition and classification of non-metallic materials, Introduction to Fibers: Concept of Fibers, Types (Properties, and application): natural – cotton, wool, jute, sisal, wood, silk, angora, and asbestos, artificial – nylon, polyester, rayon, fiber glass, polyethylene, aramid, linen, C, SiC,Al_2O_3.Production of natural and artificial fibers: Cotton, Silk, Wool, Nylon, Aramid, C, SiC, Fiberglass.

Unit - III: Glasses

Introduction, thermodynamics and formation of glasses, structural features of glasses, classification, processing, and applications of glasses. Manufacturing methods of glasses.

Unit - IV:Textiles

Textiles. Adhesives, and Foams: Introduction, classification, and applications, manufacturing methods of industrially important textiles, adhesives, and foams.

Unit - V: Advanced materials

Materials used for lasers, integrated circuits, magnetic information storage, liquid crystal display, fiber optics, nano-engineered, quantum computing, fuel, bioand smart applications.

Suggested Readings:

1. V. Raghavan: Materials Science and Engineering, Prentice-Hall.
2. W.D. Callister, Materials Science and Engineering, 10th Edition, 2020, Wiley and Sons.

Reference Books:

1. W.S. Smith: Principles of Materials Science and Engineering, McGraw-Hill.
2. Ajit Behera, Advanced Materials: An Introduction to Modern Materials Science, Springer International Publishing, 2021.

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B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
Professional Elective – II

MM615PE: Advances in Surface Engineering

Course Objectives

- This course primarily focuses on understanding, analyzing and controlling the properties of solid surfaces. It provides knowledge about techniques for altering surface properties. The advancements that have taken place in the recent times will be discussed in detail.

Course Outcomes

At the conclusion of this course, the student will be able to

- Understand the significance of surfaces and surface characteristics
- Design a method of surface coating for the given material
- Evaluate the surface characteristics to correlate with the behavior of the engineering component
- Recommend the surface engineering technique suiting to the application

Unit - I: History and background of Surface Engineering

Fundamental approach to surface engineering; scope and emergence; current trends in surface engineering and future scope of surface engineering; factors influencing the surfaces; Types of surface modification treatments; Industry oriented applications of surface engineering; Advantages and Limitations.

Unit - II: Surface Characterization Techniques

Surface characterization techniques: Principles and procedures involved; Equipment and process design; Classification; Determination of Surface characteristics viz., thickness, continuity, hardness, adhesion, porosity, and bond strength.

Unit - III: Advances in Surface Coatings-I

Necessity of advances in surface coatings; generation of water repellent surface coatings-techniques to improve wetting and surface characteristics; creation of biocompatible surfaces-techniques, principles and procedures involved.

Unit - IV: Advances in Surface Coatings-II

Factors that are responsible for the requirement of thin film coatings; Significance of thin films; Plasma assisted, and Plasma enhanced Chemical Vapor deposition (CVD) and Physical Vapor Deposition (PVD) techniques; Laser supported thin film coating techniques; Liquid phase techniques.

Unit - V:

Synthesis, processing and Characterization of nanostructured coatings; Applications of advanced surface coatings in medical filed. Polymer coatings; Futuristic view of these advanced surface coating techniques.

Suggested Readings:

1. K G Budinski, Surface Engineering for wear resistance, Prentice Hall, New Jersey,1998
2. Surface Engineering, Process fundamentals and applications, Vol I and II, Lecture Notes of SERC school of SurfaceEngineering
3. Polymer Surfaces, From Physics to Technology, F. Garbassi, M. Morra, E. Occhiello, Wiley, New York, ISBN 0471971006

Reference Books:

1. Intermolecular and Surface Forces, J.N. Israelachvili, Academic Press 2011, ISBN 9780123751829
2. Electroplating: Basic Principles and Practice - Kanan. N (Elsevier)2004

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B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
Professional Elective – II
MM616PE: Fracture Mechanics and Failure Analysis

Course objectives

- Gain an understanding of fundamentals of fracture mechanics, Griffith crack theory.
- Analyse the crack behavior in various conditions.
- Obtain a working knowledge of failure analysis.

Course Outcomes

- Fundamental understanding of fracture mechanics.
- Awareness about crack formation and crack growth in materials under various conditions.
- Able to analyze and take remedial steps in case of failure by fracture.
- Gaining theoretical knowledge on different techniques to find properties of failure.
- Designing a material to withstand different loading and service conditions.

Unit - I: Introduction to Fracture Mechanics

Fracture criteria, theoretical strength, stress-concentration factor, Griffith crack theory, strain-energy release rate. Stress Concentration effect of flaws, Effect of material properties on fracture, Cleavage, Brittle and Ductile fracture, ductile brittle transition, Modes of fracture, Stress corrosion cracking, Damage tolerance, Fracture in different materials, Fractography, Case studies.

Unit - II: Linear Elastic Fracture Mechanics

Atomic view of fracture, modes of fracture, Griffith theory, Energy release rate, instability and R Curves, compliance, tearing modulus, Stress and Displacement field in isotropic elastic materials, Airy stress function, Stress analysis of crack, Stress intensity factor (SIF), relation between K and global behaviour. Miner’s rule.

Unit – III: Elastic-Plastic Fracture Mechanics

Crack tip deformation and plastic zone size, plane stress vs plane strain, effective crack length, Irwin plastic zone correction, Dugdale approach, effect of plate thickness. J Contour Integral: Relevance and scope, J as a path-independent line integral, J as a stress intensity parameter, J-Controlled fracture, Laboratory measurement of J, Crack Tip Opening Displacement (CTOD), Relationship between CTOD, K and G, Equivalence between CTOD and J, Determination of CTOD from strip yield model.

Unit - IV: Fatigue

Introduction to fatigue, factors affecting fatigue performance, fatigue loading, constant and variable amplitude loading, some characteristics of fatigue crack, Paris Law, Mayer’s Law.

Unit - V: Creep

Introduction to creep, stages of creep, deformation mechanisms (dislocation, diffusion, grain boundary sliding), elevated temperature fracture conditions, equicohesive temperature, creep tests, designing criteria of components. Nabarro-Herring creep, Coble creep, Monkman and Grant equations.

Suggested Readings:

1. Fracture Mechanics: Fundamentals and Applications, T.L. Anderson, CRC Press, Inc., 1995.
2. Fracture and Fatigue Control in Structures, S.T. Rolfe and J.M. Barsom, Prentice-Hall, 1972.
3. Case Histories in Failure Analysis, ASM, Ohio, 1979.

Reference Books:

1. ASM Handbook: Fatigue and Fracture, S.R. Lampman, (Rechnical Ed.), ASM International, 1996.
2. Elementary Engineering Fracture Mechanics, David Broek, Scjtoff&Noordhoff, 1978.
3. Failure Analysis – R.W. Hertzberg, Deformation of Fracture Mechanics of Engineering Materials – John Wiley & Sons Publications, 1995.

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B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
MM651PC: Metal Joining Lab

Course Objective

- This Laboratory course is designed to make the student to understand and demonstrate the various types Welding processes and its variables, testing methods and correlation between microstructure and Mechanical properties of the Welded joints.

Course Outcomes

- Select process parameters by bead on plate trial.
- Gain knowledge in practical aspects of SMAW, GMAW SAW
- Gain knowledge on welding of carbon steel,
- To carryout characterization and testing techniques for welded joints.

Experiments:

1. Study of gas welding equipment and process. Identification of flames, making Butt joint with gas welding.
2. Study of Arc welding process, comparison of the bead geometry with DCSP, DCRP and A.C.
3. Study of resistance spot welding process and plot the variation of spot area with time and current variation
4. Study of Tungsten Inert Gas (TIG) welding process and measurement of temperature during TIG welding process.
5. Study of fundamental aspects of Submerged Arc Welding (SAW) process and finding out deposition efficiency of the process.
6. Study of fundamental aspects of MIG welding process
7. To conduct tests on weld joints to evaluate the mechanical properties of the joints, like bend test and ram tensile test.
8. To evaluate the microstructure of welded joint and understand the structural difference in Weld zone, Heat Affected Zone and Base metal.

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B.Tech in Metallurgical and Materials Engineering
VI Semester Syllabus
MM652PC: Metallurgical Computations Lab

Course Objective

- This Laboratory course is designed to make the student to understand and demonstrate
- This lab course is mainly designed to provide hands on practice on the computational methods for evaluation of metallurgical and materials engineering properties

Course Outcomes

Upon successful completion of this course, the student will be able to write simple computational methods

- For phase rule, ASTM grain size and packing factor
- For Calculation of UTS and YS, elongation and reduction in area and Hall Petch relation
- For determination of heat transfer data
- For determination of free energy, entropy and enthalpy

LIST OF EXPERIMENTS: Programming of

1. Estimation of proportion of phases using Lever rule, ASTM grain size and packing factor for bcc, fcc and hcp
2. Determination of ΔH using Kirchhoff's equation, ΔG from thermal data and Entropy
3. To solve the problems on conductions
4. Calculation of UTS and YS and Hall Petch relation
5. Functions in computing free energy of common metallurgical systems from enthalpy and entropy or heat capacity and determination of temperature of reduction of metal oxides.
6. Computation of % CO/CO2 at different heights with a given function of temperature profile along the height of BF and Simulations of Blast furnace reduction reactions at various heights
7. Write a program to simulate mechanical properties of pure metal or simple binary isomorphous / eutectic system from given composition, heat treatment condition, % cold working etc.
8. Write a program to design sacrificial anode cathodic protection of underground pipeline with user given pipe dimension & electrochemical properties

Suggested Readings:

1. Computer oriented Numerical methods – V. Rajaraman (PHI Publications)
2. Computer programming and Numerical methods – S. Saran
3. Numerical methods in engineering – Mario G. Salvadori and Melvin L. Baron
4. Matrix operation on Computer – L.L. Brirud (LCUE Publication)

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B.Tech in Metallurgical and Materials Engineering
VII Semester Syllabus
MM701PC: Corrosion Engineering of Materials

Course objectives

- To familiarize the student with the extent and importance of material degradation.
- To study various aspects of corrosion of materials and its control.

Course outcomes

After completing this course, the student should be able to

- To understand the fundamentals of electrometallurgical principles and their application to various electrometallurgical processes
- Understanding the thermodynamic and Kinetics of Corrosion processes
- To understand and appreciate different forms of corrosion, characteristic features and their mechanism
- To understand corrosion preventive measures and apply specific preventive measures based on the cause for the corrosion
- To understand the effect and mechanism of environment on the degradation of composite and polymeric materials

Unit - I: Fundamentals of electrochemistry and corrosion

Introduction to Environmental Degradation of Materials, Forms of environmental degradation, Importance of corrosion studies, cost of corrosion. Fundamental Definition of Corrosion. Review of electrochemical Principles – Faraday's Laws of Electrolysis. Electrode Potential and its determination. Primary and Secondary electrodes. Reversible and Irreversible electrode potentials, EMF series – its applications and limitations. Nernst Equation – Derivation and its application to the concepts of Corrosion. Classification of Corrosion processes. Electrochemical aspects of Corrosion.

Unit - II: Thermodynamic and Kinetic Concepts of corrosion

Thermodynamic concepts of Corrosion and Free Energy relation. Construction and application of the Pourbaix diagrams. Concept of Exchange current density, polarization, over potential – Hydrogen over potential and Oxygen over Potential. Classification of polarization – Activation Polarization, Concentration Polarization, Resistance Polarization and combined Polarization. Mixed Potential Theory and Tafel equations. Classification of polarization – Activation Polarization, Concentration Polarization, Resistance Polarization. Passivity – concepts and Mechanism. Corrosion rate measurement by weight loss methods, Tafel's extrapolation method, and Linear Polarization resistance (LPR) Passivity.

Unit - III: Forms of Corrosion

ASM Classification, Characteristic features, Mechanism, Factors influencing, and remedial measures of Uniform corrosion, Galvanic Corrosion, Crevice Corrosion, Pitting Corrosion, Intergranular Corrosion, Erosion Corrosion, Selective leaching, Stress Corrosion Cracking, Hydrogen Embrittlement. Microbil Corrosion Process.

Unit - IV: Corrosion Prevention

Materials selection, Alteration of Environment, Design Aspects, Inhibitors, Cathodic and anodic protection, Coatings - Organic and Inorganic Coatings

Unit - V: Degradation of Non-Metallic Materials

Fundamental understanding of composite and polymer materials. Mechanism of degradation of polymeric materials and composite materials and preventive measures

Suggested Readings:

1. Corrosion Engineering, Mars. G. Fontana, McGraw Hill Education, 2017
2. Electrochemical Techniques in Corrosion Science and Engineering. R.G. Kelly, J.R. Scully,D.W. Shoesmith, R.G. Buchheit, CRC Press., 2002

Reference Books:

1. Corrosion: Metal / Environment Reactions, Volume 1, L.L. Shreir, R.A. Jarman, G.T. Burstein, Butterworth-Heinemann, 1994.
2. Principles and Prevention of Corrosion, Denny A. Jones, Pearson, 1995.

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B.Tech in Metallurgical and Materials Engineering
VII Semester Syllabus
Professional Elective III
MM711PE: Materials Data Science and Informatics

Course objectives

- Solve materials and metallurgical problems through data analytics and data science

Course Outcomes

At the end of the course the student should be able to
- Understand data and informatics
- Know the basics of Python language
- Know the Data science approach and visualize metallurgical data
- Know data analysis and model development using data
- Know model evaluation and exploration

Unit - I

Introduction to data science, types of data, variables and their types, scale of measurement, Examples with materials data. Materials data science and its needs in industry and materials research perspective. Concept of materials informatics, Material Discovery and Development, History of Materials Development Cycles, Need for accelerated materials development and deployment. Materials Innovation and Ecosystem. Big Data.

Unit - II

Getting Python, white space formatting, modules, arithmetic, functions, strings, exceptions, lists, tuples, dictionaries, default dist, counter, sets, control flow, truthiness, sorting, list comprehensions, generators and iterators, randomness, regular expressions, object-oriented programming, functional tools, enumerate, zip and argument unpacking, args and kwargs

Unit - III

Data Science approach: Terminology and Components of Data Science, Getting and Cleaning Data, Data Statistics, Descriptive and Inferential Statistics, Event Space, Probability, Distributions and Hypothesis Testing Summarizing and Visualizing Data: Example with a material and metallurgical data.

Unit - IV

Univariate and Multivariate Exploratory Data Analysis. Feature extraction and feature selection. Simple example with materials data. Model development using data, learning algorithms: supervise, unsupervised and reinforcement learning, tools, and techniques. Functional mapping, Classification, and pattern recognition, rule base model etc.

Unit - V

Data Pre-processing, Model Evaluation and Ensembles. stages of data science approach of problem solving, Descriptive, diagnostic, predictive and prescriptive analytics of materials data. Example with industrial and laboratory data. Structure-Property Linkages using a Data Science Approach, exploring new materials space using data science informatics.

Suggested Readings:

1. Joel Grus, Data science from scratch, O'Reilly Media, USA, First edition, 2
2. Krishna Rajan (Ed), Elsevier, Informatics for Materials Science and Engineering. Data-driven Discovery for Accelerated Experimentation and Application, Elsevier, First Edition, 2013.

Reference Books:,

1. Web resource: https://www.coursera.org/learn/material-informatics
2. Amit Konar, Computational Intelligence: principles, techniques and application, Springer, NY, First Edition 2007.

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B.Tech in Metallurgical and Materials Engineering
VII Semester Syllabus
Professional Elective III
MM712PE: Additive Manufacturing of Materials

Course Objective

- The course objective is to given fundamental knowledge on additive manufacturing methods, materials used for additive, and metallurgical aspects in additive manufacturing

Course Outcomes

By the end of the course student will be able to

- Appreciate the advantages and limitations of additive manufacturing methods over conventional manufacturing methods
- Gain knowledge on different materials and their properties used for Additive manufacturing along with tooling for additive manufacturing
- Understand different additive manufacturing techniques
- Gain knowledge on different necessary post-processing methods
- Gain knowledge on different metallurgical aspects on Advanced Manufacturing products

Unit - I: Introduction

Introduction to Additive Manufacturing, Classification, Advantages, and disadvantages of Additive Manufacturing process. comparison of Additive v/sConventional Manufacturing processes, Applications of Additive Manufacturing process, CAD Data formats, Data translation, Data loss, STL format

Unit - II: Materials for Additive Manufacturing

Materials: Polymers, Metals, Non-Metals, Ceramics, Composites etc, Raw material Preparation and their desired properties, Support Materials; Additive Manufacturing Equipment and tooling; Process: Process parameter, Process Selection for various applications. Various forms of raw material- Liquid, Solid, Wire, Powder

Unit -III: Additive Manufacturing Techniques

a. **Binder Jetting**: Materials, Process Benefits and Drawbacks, Applications of Binder Jetting Processes.
b. **Sheet Lamination Methods**: Bonding Mechanisms, Materials, Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC), LOM and UC applications
c. **Powder Bed Fusion Processes**:
   Powder making for AM processes, powder characteristics and characterization Selective laser Sintering/ Melting (SLS/ SLM), Materials for SLM, Powder fusion mechanisms, Applications of Powder Bed Fusion Processes

d. **Directed Energy Deposition AM Processes**: Process, Laser, Processing-structure-properties, relationships, Benefits and drawbacks, Applications of Directed Energy Deposition Processes, Multifunctional and graded materials in AM
e. **Wire Arc Additive Manufacturing** & **Electron Beam Additive Manufacturing**: Process, parameters, applications, advantages, and disadvantages.

Unit – IV: Post Processing of AM Parts

a. Support Material Removal, Surface Texture Improvement
b. Accuracy Improvement, Aesthetic Improvement
c. Property enhancements
d. Post-processing techniques: Shot-peening, Heat treatment, Hot isostatic pressing

Unit – V: Materials Science Concepts in AM of metals

a. Defects in various AM processes- porosity, lack of fusion, residual stresses
b. Dislocations and strengthening mechanisms.
c. Grain structure
d. Role of solidification rate
e. Phase transformations & Heat treatment: Development of microstructure
f. Evolution of non-equilibrium structure
g. Structure-property relationship

References Books:

1. Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Ian Gibson, David W Rosen, Brent Stucker, Springer, 2015, 2nd Edition.
2. 3D Printing and Additive Manufacturing: Principles & Applications, Chua Chee Kai, Leong Kah Fai, World Scientific, 2015, 4th Edition.
3. Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma, Springer, 2004.
4. Additive Manufacturing, Second Edition, Amit Bandyopadhyay Susmita Bose, CRC Press Taylor & Francis Group, 2020.
5. Additive Manufacturing: Principles, Technologies and Applications, C.P Paul, A.N Jinoop, McGrawHill, 2021.
6. Milewski, J.O., 2017. Additive manufacturing of metals. Cham: Springer International Publishing.
7. Balasubramanian, K.R. and Senthilkumar, V. eds., 2020. Additive Manufacturing Applications for Metals and Composites. IGI Global.

Online resources:

1. https://www.nist.gov/additive-manufacturing
2. https://www.metal-am.com/
3. http://additivemanufacturing.com/basics/
4. https://www.3dprintingindustry.com/
5. https://www.thingiverse.com/
6. https://reprap.org/wiki/RepRap

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B.Tech in Metallurgical and Materials Engineering
VII Semester Syllabus
Professional Elective III
MM713PE: Advanced Manufacturing Techniques

Course Objective

- This course aims at making student to understand and design a material for a given application considering the composition, manufacturing process and properties that are required in service.

Course Outcomes

At the conclusion of this course, the student will be able to

- Understand various manufacturing technologies for different materials.
- Correlate between manufacturing technology and the characteristics of Materials.
- Understand the relationship between materials selection, manufacturing process and applications.
- Design the appropriate criteria to facilitate the manufacturing technology suiting to the service environment.

Unit - I: Introduction

Background of various Manufacturing Technologies; Identification of processing parameters: Dynamic materials modelling and definition, safe processing zones, identification of safe window of processing.

Unit - II: Advanced Metalworking Processes

A holistic approach on Metalworking processes; Bulk deformation process: Isothermal forging, disc, ring rolling, incremental forging.

Severe Plastic Deformation Processes: Introduction, Classification, Principles and procedures involved; Design parameters; necessary equipment; Advantages and Limitations; Applications.

Unit - III: Advanced Metal Powder Technologies

Significance of metal powder technology in manufacturing engineering; classifications, advances in metal powder techniques: Spray forming, Cold and Hot Isostatic Pressing (HIP), hot pressing; Powder Extrusion. Additive Manufacturing: Introduction, Classification, Principles involved, Process design parameters; Advantages and shortcomings; Applications.

Unit - IV: Advanced Casting Processes

Introduction; An overview of metal casting processes; recent advances in casting technology; Directional solidification and single crystal component manufacturing, Continuous casting, Rapid solidification of metals- Applications.

Unit - V: Advanced metal joining processes:

Narrow Gap laser Welding (NGLW) process, Microwave welding, Laser hybrid welding, Magnetic arc welding. Other industrially applied recent welding techniques.

Suggested Readings:

1. Advanced Techniques to evaluate hot workability of materials - KP Rao, YVRK Prasad
2. Comprehensive Materials Processing, Elsevier
3. Handbook of Workability and Process Design- G.E. Dieter, SL Semiatin

Reference Books:

1. Rapid protoyping of materials - Marquis FDS
2. Rapid prototyping and manufacturing Fundamentals and Stereo Lithography- PF Jacobs
3. Rapid prototyping: Laser based and Other technologies- PK Venuvinod
4. Hot Working Guide - A compendium of processing Maps -Authors - YVRK Prasad, Sasidhara
5. ASM Handbook Volume -7 Powder Metal Technology & Applications

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B.Tech in Metallurgical and Materials Engineering
VII Semester Syllabus
Professional Elective V
MM714PE: Transport Phenomena in Materials Engineering

Course objectives

- This course will introduce the concepts of fluid flow, heat transfer and mass transfer with processing of engineering materials as the focus.

Course outcomes

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

- Pose a problem in transport phenomena as a balance equation
- Identify suitable boundary conditions for the problem
- Solve simple partial differential equations relevant to transport phenomena
- Plot different parameters
- Design a pilot plant

Unit - I: Introduction to Transport phenomena

Properties of fluids,Units and Dimensional Analysis. Molecular theory of viscosity of gas/liquid,Newton's law of viscosity, Reynolds experiments, Types of fluid flow, Types of transport

Unit - II: Momentum transfer

Equation of continuity and motion, Shell momentum balance and velocity profile, concept of velocity boundary layer, Navier-Stokes equation, and its applications, Bernoulli's equation, Friction factor, Fluid flow in packed bed, Darcy's law

Unit - III: Heat transfer

Fundamentals of heat conduction, convection, radiation, and their combined effect. Fourier's law of heat conduction, Steady state and unsteady state conduction in solids, Natural convection, forced convection, concept of heat transfer coefficient and thermal boundary layer, heat transfer through a composite wall, Radiation heat transfer

Unit - IV Mass transfer

Diffusivity and steady state diffusion, Fick's laws, Unsteady state mass transfer, concept of mass transfer coefficient, concentration boundary layer.

Unit - V Dimensionless numbers

Similarities of momentum, mass, and energy transfer. Dimensionless numbers, their physical meaning, the relations between them and their applications. Similarity criteria and introduction to pilot plant studies

Suggested Readings:

1. Introduction to Transport Phenomena in Materials Engineering, David R Gaskell, Momentum Press 2nd Edition 2012
2. Fundamental of Transport Phenomena and Metallurgical Process Modeling, Sujay Kumar Dutta, Springer Singapore, 1st Edition.

Reference Books:

1. Transport Phenomena in Materials Processing: D.R. Poirier and G.H. Geiger, TMS
2. Transport phenomena, 2nd Edition: R. Byron Bird, Warren E. Stewart, and Edwin N Lightfoot. John Wiley & Sons

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B.Tech in Metallurgical and Materials Engineering
VII Semester Syllabus Professional Elective V
MM715PE: Light Metals and Alloys

Course Objectives

The prime aim of this course is to understand and gain

- Basic knowledge of light metals and alloys, strengthening mechanisms and their selection based on applications in design of industrial components
- Knowledge of Physical metallurgy of Al alloys for aerospace applications
- Knowledge of design and selection of Bealloys in different engineering applications and processing of Al alloys for mechanical systems.
- Knowledge of Physical metallurgy of Ti alloys and their processing for industrial applications
- Knowledge of production, processing of physical metallurgy of Mg alloys for industrial applications

Course Outcomes

Upon successful completion of this course, the students will be able to

- Learn about Al alloys and can analyze the mechanical properties of Al alloys in real time aerospace applications
- Learn and apply physical metallurgy aspects and corrosion aspects of Ti alloys in industry
- Learn and apply processing of Ti alloys along with physical metallurgy aspects in other industrialapplications.
- Learn and apply physical metallurgy and corrosion aspects of Mg alloys in industry
- Apply their basic knowledge in selection of light metals based on design and applications.

Unit - I

General introduction –Light metals and alloys, strengthening by solid solution, precipitation, dispersion of second phase particles, grain refinement and work hardening; Scenario of India in worlds production of light metals and alloys.

Unit - II

Aluminum alloys: Classification, properties,applications;Heat treatment of Al-Cu, Al-Mg, Al-Zn, Al-Mn and Al-Si,Al-Li systems,Ternary phase diagrams, Al-Cu-Mg, Al-Si-Mg and Al-Zn-Mg systems

Unit - III

Development of high strength Aluminum alloys by non-equilibrium processing routes such as rapid solidification and powder metallurgy. Applications in consumer, automotive and aerospace industry.

Processing of Al-alloys; Beryllium alloys: Classification properties and applications.

Unit - IV

Commercially Pure Titanium and its properties, applications, interstitial solid solutions of Titanium, Titanium alloys, Strengthening mechanisms of Ti alloy,alpha Ti alloys, Beta Ti-alloys, alpha plus Beta Ti alloys,Heat treatment, Properties and applications of Ti-8Al-1Mo-1V, Ti-6Al-4V, Ti-5553 alloys; Processing of Ti alloys.

Unit - V

Magnesium Alloys: Properties,Designation, Heat treatment of Magnesium alloys Mg-Sn, Mg-Zn, Mg-Gd, Mg-Li systems. Corrosion resistance of Mg-alloys; Development of high strength magnesium alloys. Production and processing of Mg alloys; Applications in consumer, automotive and aerospace industry.

Suggested Readings:

1. Heat treatment, structure, and properties of nonferrous alloys - Charlie Brooks, ASM Metals Park, Ohio, USA.
2. I.J.Polmear, Light Alloys - From Traditional alloys to nanocrystals, Fourth Edition, Butterworth Heinemann, 2005.
3. D.H. Kirkwood, M. Surey, P. Kapranos, H.V. Atkinson, K.P. Young, Semisolid Processing of Alloys, Springer Series in materials Science, 2010.
4. M. Gupta, N.M.L. Sharon, Magnesium, Magnesium Alloys, and Magnesium Composites, Wiley, 2011.

Reference Books:

1. Introduction to Physical Metallurgy – S. H. Avner
2. Engineering Physical Metallurgy – Lakhtin
3. R.W.Heine, C.R.Loper, P.C.Rosenthal, Principles of Metal Casting,Tata McGraw Hill, 1976.
4. G. Lutjering, J.C. Williams, Titanium, Springer, 2007

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B.Tech in Metallurgical and Materials Engineering
VII Semester Syllabus
(Professional Elective –IV)
MM716PE: CERAMICS SCIENCE AND TECHNOLOGY

Course objectives

- This course is intended to provide in depth knowledge on processing ceramic materials including structure, properties, phase transformations, applications, and fabrication methods of ceramics.

Course Outcomes

Through this course, the student will be able

- To understand the bond structure, crystal structure and properties of ceramics and with other engineering materials.
- To understand the physical nature and phase diagrams of ceramics to understand the mechanical and physical behavior of ceramics.
- To understand various methods of ceramic powder preparation methods to meet the industrial needs and real time applications.
- The student will be understanding various manufacturing techniques of ceramic components.

Unit - I: Introduction and Crystal structures of Ceramics

Definition, Classification of Ceramics, Traditional Ceramics, Structural Ceramics, Ceramic super conductors. Crystal structures in Ceramics, Grouping of ions and Pauling’srules, Oxide structures, Silicate structures, Glass formation, Models of glass structure, Types of glasses.

Unit - II: Equilibrium Diagrams of Ceramic Systems

Two component systems (Binary Diagrams) - Al_2O_3 – SiO_2, CaO- MgO and BaO – TiO_2; and Three component systems (Ternary Diagrams) MgO – Al_2O_3 – SiO_2

Unit - III: Properties of Ceramics

Single phase and multi-phase ceramics, microstructure, Mechanical, Thermal, Electrical, Optical, Magnetic, and Chemical properties of ceramic materials

Unit - IV: Ceramic Powder Preparation Techniques

Synthesis of Ceramic powders, microstructure, Sol-gel technology – Precipitation, Coprecipitation and Hydrothermal precipitation techniques. Preparation of Al_2O_3, ZrO_2, SiC, Si_3N_4, BN,&B_4C.

Unit - V: Ceramic Processing Techniques

Hot Pressing, Hot Isostatic Pressing, (HIP). Spark Plasma Sintering. Sintering, Sinter/HIP, Injection moulding, Slip casting, Tape casting, Gel casting, Extrusion.

Suggested Readings:

1. Introduction to Ceramics,W.D. Kingery et al , John Wiley
2. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramanian, John Wiley & Sons, NY, Indian edition, 2007.

Reference Books:

1. FINCER proceedings of workshop on fine ceramics synthesis, properties and applications, T.R. Rammohan et al.
2. Fundamentals of Ceramics ... Barsoum, M.
3. Mechanical Properties, Failure Behaviour, Material Selection, D. Munz& T. Fett
4. Ceramic Science and Technology, Vol. 2 Material Selection and Properties Ed., Ralf Riedel and I ,Wei Chen, Wiley, CH

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B.Tech in Metallurgical and Materials Engineering
VII Semester Syllabus
MM751PC: Corrosion Engineering of Materials Lab

Course Objectives

- Is to understand the Thermodynamic aspects of corrosion
- Is to understand the cathodic electrometallurgical processes through electroplating
- Is to understand various
- Is to understand principles of through different corrosion experiments

Course Outcomes

- To understand the influence of the process variables, Current Density, on current Efficiency
- To apply the concepts of Thermodynamics in corrosion process
- To gain hands on experience and principles on different corrosion processes
- To understand the influence of Environmental factors on corrosion process
- To gain knowledge on different methods to estimate the rate of corrosion

LIST OF EXPERIMENTS:

1. Study the effect of concentration and temperature on conductivity of an aqueous electrolyte.
2. Verification of Faraday's laws of electrolysis.
3. Determine the influence of cathodic current density on current efficiency by electroplating (Cu and Ni electroplating).
4. Determination of EMF of Common metals.
5. Determination of corrosion rate of common metals through weight loss technique.
6. Study the galvanic corrosion by constructing different galvanic couples.
7. To study the intergranular corrosion of Austenitic stainless steels.
8. Study the influence of coating on rate corrosion on steel samples.
9. Study the influence of Environmental effect (pH, Temperature, oxidizers, velocity) on rate of corrosion

List of equipment:

1. Rectifier
2. Ammeters
3. Rheostats
4. D C Regulated Power Supply instrument
5. Multimeters
6. Conductometers
7. Digital weighing balance
8. Potentiometers

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B.Tech in Metallurgical and Materials Engineering
VII Semester Syllabus
MM752PC: Modelling and Simulation Lab

Course objectives

- This course is designed to impart the students' hands-on experience on the various metallurgical problems by modelling and simulation techniques with the help of programming languages as well as various software packages.

Course outcomes

Students will acquire a hands-on training on

- Computational Modeling & Simulation Technique
- Determine crystal structure and Plot different crystal structures
- Model Gating and Riser design
- Charge input to Blast Furnace
- Plot Pourbaix & binary phase diagrams

LIST OF EXPERIMENTS:

1. Computing heat and mass calculations of chemical reactions.
2. Determination of Crystal structures using computer principles.
3. Programming of pressurized and non-pressurized Gating system.
4. Programming on calculation of electrode potential at non-standard conditions.
5. Programming of Risering system.
6. Programming to determine charge input to get the required output of product in a blast furnace.
7. Computation of Binary Phase diagram.
8. Computation of Pourbaix diagram
9. Programming to plot simple cubic, BCC and FCC crystal structures

Suggested Readings:

1. MATLAB manual: Getting started with MATLAB
2. Computer oriented Numerical methods – V. Rajaraman (PHI Publications)
3. Computer programming and Numerical methods – S. Saran
4. Numerical methods in engineering – Mario G. Salvadori and Melvin L. Baron
5. Matrix operation on Computer – L.L. Brirud (LCUE Publication)

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B.Tech in Metallurgical and Materials Engineering
VIII Semester Syllabus
(Professional Elective –V)
MM811PE: Artificial Intelligence in Materials Engineering

Course objective

- Understand AI and its application in Materials Engineering

Course Outcomes

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

- Know the Artificial Intelligence and Machine Learning
- Know fundamentals of artificial neural networks
- Solve a materials problem using artificial neural networks
- Know genetic algorithms and its application in materials engineering
- Know data mining and Fuzzy logic its application in materials engineering

Unit - I

Introduction to artificial intelligence and machine learning, History, Philosophy, and Definitions of AI, The Foundation of AI, correlation between materials structure, properties, phenomena, and process. Scope of solving industrial and research-based materials problem using AI. Role of AI in solving materials science problems. Accelerating Materials Development and Deployment.

Unit - II

Fundamental of Artificial neural network, basic elements and principles, types, etc. Supervise unsupervised and reinforcement learning. Back propagation algorithm, hyper parameters loss function transfer function and optimization algorithms, recent development, and deep learning.

Unit - III

Applications and examples of artificial neural network in solving materials problem, structure properties linking, process property linking. Artificial neural network in MATLAB, Activation functions, splitting data into train, validation and test data, performance criteria, demo of ANN for constitutive behavior of metals

Unit - IV

Framing a material problem as optimization search problem, classical and heuristic search. local and global search, Genetic Algorithms as AI based search tool, single and multi-criteria search, constraints etc. Example study with solving the blast furnace operation-based problem /coiling temperature in Hot strip mill, design of steel and alloys.

Unit - V

Reasoning and Association rule mining for solving materials problem, decision trees, fuzzy logic and reasoning, fuzzy set, fuzziness in materials systems, a fuzzy variable with metallurgical examples, fuzzy inference system case example of fuzzy modelling materials problem solving.

Rough set theory and its applications in alloy design. Hybrid system and their application in materials with examples of more complex problems

Suggested Readings:

1. Dan W. Patterson, Introduction to AI & Expert System, PHI, First Edition, 2015.
2. Russel & Norvig, Artificial Intelligence: A Modern Approach, Pearson Education, by Stuart Russell and Peter Norvig. Cahn, Fourth edition, 2019
3. Artificial Intelligence: Elaine Rich, Kevin Knight, Mc-Graw Hill, 2nd Edition 1991.
4. RajalingappaShanmugamani, Deep learning for Computer Vision, Packt Publication, Mumbai India, First Edition, 2018.
5. S. Haykin, Neural Networks; a comprehensive foundation, Prentice-Hall India Pvt Ltd. 2^{nd} edition 2003.

Reference Books:

1. Neuro-Fuzzy and Soft Computing: A computational approach to learning and machine intelligence, Indian Edition, Prentice Hall, USA 1997.
2. David E. Goldberg, Genetic Algorithms in search of optimization and machine Learning, Pearson Education Inc. Fifth Indian Reprint, 2002
3. Luger Artificial Intelligence, Pearson Education India; 5th edition, 2008.
4. S. Rajasekaran, G.A.V. Pai: Neural networks, Fuzzy Logic and Genetic Algorithms Synthesis and Applications, Prentice-Hall of India.

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B.Tech in Metallurgical and Materials Engineering
VIII Semester Syllabus
(Professional Elective –V)
MM812PE: Advanced Materials

Course objectives

- This course has a prime objective of educating the students in such a way that the student will have an opportunity to study all significant materials under one umbrella. The Classification, manufacture and applications of these materials are dealt in detail.

Course Outcomes

Through this course, the student will be able

- Fundamentals of Nano materials, CCC, Cermets
- Understand the structure, properties, and applications of Intermetallic Compounds
- KnowBiomaterials, Functionally Gradient Materials and Shape Memory Alloys
- Know the processing and applications of Refractory metals and Cermets
- Design an advanced system / component with the knowledge acquired through this course.

Unit - I: Nanomaterials

Introduction–Classification of Nanomaterials, synthesis methods.
Carbon-CarbonComposites: Introduction, Preparation of carbon fibres, Reinforcement performs, knitting, braiding, weaving, filament winding, helical winding, polar winding. Making of carbon-carbon composites advantages and disadvantages, Properties and Application.

Unit - II: IntermetallicCompounds

Introduction, Types of Intermetallic compounds, Ni-Al, Fe-Al, and Ti-Al system, Preparation, properties, and Application of Intermetallic compounds.

Unit - III: Biomaterials

Properties of Biomaterials, Metallic biomaterials: Stainless steels, Cobalt and Titanium based materials. Polymers and Ceramics.

Unit - IV: Functionally Gradient Materials (**FGM**)

Classification of FGMS, Preparations, Properties and Applications of different FGM system.
Shape Memory Alloys (**SMA**): Introduction, shape memory effect, classification of shape memory alloys, Composition, Properties and Application of SMAs.

Unit - V: Cermets

Introduction. Classification. Fabrication, techniques, Bonding and microstructure, Oxide cermets, Carbide and Carbonitride cermets, and Steel-bonded cermet: Properties and Applications.

Refractory Metals and Alloys: Introduction, Manufacturing, Preparations, Properties and Application of W,Mo, Nb, Ta, Re

Suggested Readings:

1. Materials Science and Technology – RW Cahn.
2. Wiley Interscience: Book Home – Handbook of Advanced Materials.

Reference Books:

1. High Temperature Materials-1 E Campbell
2. Advanced materials: Refractory fibres, fibrous metals, composites –Charles Zigniew Carroll-Porczynski.
3. ASM Metals Handbook Vol 1 & Vol.2
4. Handbook of advanced materials: enabling new designs – James K. Wessel.

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B.Tech in Metallurgical and Materials Engineering
VIII Semester Syllabus
(Professional Elective –V)
MM813PE: Non-Destructive Evaluation

Course objective

- The objective of the course is to introduce various non-destructive evaluation techniques applied to impact and test quality of manufacture products obtained by various manufacturing techniques such as welding, rolling, forging, casting, powder metallurgy etc. This subject also provides certification aspects of commercial products

Course Outcomes

- Understanding importance of NDE role in industry.
- Knowing codes & standards, defects, procedures, recent developments.
- Evaluate the materials and structures for the causes of discontinuities, which interfere with the usefulness of the part by various NDT methods.
- Gaining knowledge on advanced NDE Techniques.
- Design nondestructive methods for inspection and evaluation of materials.

Unit - I: Introduction, Visual Methods, LPT

Introduction, codes and standard, Defects in weldments, forgings, rolling products, castings, Procedure to select a Non-Destructive Technique for an application. Visual inspection, In-situ metallography. Liquid Penetrant Testing: Principles, Process, Penetrant systems, Liquid-penetrant materials, Emulsifiers, cleaners developers, sensitivity, Advantages, Limitations, Applications. Examples of defects seen with LPT.

Unit - II: Magnetic Particle Testing

Physics of magnetism, Advantages, Limitations, Methods of generating fields, magnetic particles and suspending liquids,Magnetography, field sensitive probes, applications. Measurement of metal properties. Examples of defects seen with MPT.

Unit - III: Radiographic Methods

Limitations, Principles of radiography, sources of radiation, Ionisingradiation - X-rays sources, gama-rays sources, recording of radiation, Radiographic sensitivity, Fluoroscopic methods, special techniques, Radiation safety.Examples of defects seen with RT.

Unit - IV: Ultrasonic Testing of Materials

Advantages, disadvantages, Applications, Generation of. Ultrasonic waves, general characteristics of ultrasonic waves, methods and instruments for ultrasonic materials testing, signal Processing,PAUT, TOFD, C-Scan. Examples of defects seen with UT.

Unit - V: Advanced methods

Eddy current method, Acoustic Emission method, Leak detection, Thermal inspection, XRF, Residual Stress Measurement using XRD. Fractography by electron microscopes, Structural Health Monitering.

Suggested Readings:

1. Non-Destructive Testing by P. Halmshaw
2. Practical Non Destructive testing, Baldev Raj, T.Jayakumar, M. Thavasimuthu, Woodhead Publishing, 2002

Reference Books:

1. Metals Handbook Vol.II, Nondestructive inspection and quality control
2. ASME SECTION V, Boiler and Pressure Vessel Code

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B.Tech in Metallurgical and Materials Engineering
VIII Semester Syllabus
(Professional Elective –VI)
MM814PE: Design and Selection of Materials for High Temperature Applications

Course Objective

- The prime objective of this industryoriented course is to introduce the high temperature applications to the undergraduate students. The course will give an insight into the criteria to be followed by the engineering materials to be applied at elevated temperatures. It will focus on the analysis of failures of materials that occur during the in service. The course will throw light on some of the successful engineered conventional alloys that are applied at high temperatures.

Course Outcomes

At the conclusion of the course, the students will be able to

- Understand the significance of the alloys for application at elevated temperatures
- Analyze the factors that influence the behavior of materials at high temperatures
- Recommend the preventive measures to be adopted to withstand the high temperature failures
- Design the optimum fabrication process for alloys to be applied successfully at elevated temperature.

Unit - I: High temperature Materials

Introduction to high temperature materials, Characteristics of high temperature materials; Super alloys: Fe-Ni base, Ni base super alloys, Cobalt base superalloys; Intermetallics: Ti-Aluminide systems; High temperature ceramics: refractory silicides and borosilicides; Composites.

Unit - II: Properties of high temperature materials:

Creep properties: Larson–Miller approach for the ranking of creep performance, High temperature Corrosion, LCF, TMF, Creep Fatigue environmental Interaction. Case studies on Structure-property correlation of Super alloys, Intermetallics and Ceramics.

Unit - III: Design guidelines

Factors to be considered for design high temperature applications: The design flow chart for an identification and clarification of task through concept, embodiment and detailed analysis to a product specification. Materials selection in mechanical design: the interaction between function, material, process and shape.

Unit - IV: Approach to Materials Selection

Establishing design requirements, material screening ranking, researching specific candidates, applying specific cultural constraints to the selection process, Ease of manufacturing; Definition performance indices in conjunction with Ashby-material property charts. Case studies: blades and high-pressure vessels.

Unit - V: Few Case studies

Case studies on Material selection and design for high temperature Applications: Aero engine components: turbine discs for an aero engine, Single crystals for super alloys;Nuclear reactors and hypersonic jet engines.

Suggested Readings:

1. M. F. Ashby, Materials Selection in Mechanical Design, Elsevier Publication, 2005
2. Material Selection and Design, Vol 20, ASM Handbook, ASM International
3. Material Selection and Design, Vol 20, ASM Handbook, ASM International

Reference Books:

1. J. G. Gerdeen, H. W. Lord and R. A. L. Rorrer, Engineering Design with Polymers and Composites, Taylor & Francis, 2005
2. M. F. Ashby and K. Johnson, Materials and Design, Butterworth Publication, 2002
3. The superalloys: fundamentals and applications, 2005, Roger C. Reed, Cambridge University press
4. V. John, *Introduction to Engineering Materials*, 3rd ed., Industrial Press, 1992

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B.Tech in Metallurgical and Materials Engineering
VIII Semester Syllabus
(Professional Elective –VI)
MM815PE: Materials for Automotive Applications

Course Objectives

- Knowledge on properties of engineering materials
- To select suitable materials for design
- Materials selection criteria for engine and transmission systems
- Different materials used for automotive structures.
- Different electronic materials for automotive applications

Course Outcomes

The student will be able to

- Gain knowledge on Selection criteria of materials based on design charts and functional requirements
- Understand the Selection criteria for various components and importance.
- Understand different materials used for automotive engines and transmission.
- Select proper material for Automobile applications
- Understand different materials used for sensors in a vehicle

Unit - I: Basis for Material Selection for Automotive Applications

Selection strategy, Attribute limits and Material indices, structural index. Selection procedure: understanding material properties using materials selection charts, Design process - types of design, design requirements, Function, Material attributes, Shape and Manufacturing processes. Systematic process selection, Energy consumption for production, Material costs, Availability, Recyclability. Environmental consideration: Materials and the environment-selection of materials.

Unit - II: Materials for Automotive Body

Introduction to nomenclature of automotive body components. Property requirements for different components of automotive body structure. Selection of materials based on required properties for automotive structures – steels, Al alloys, Mg Alloys, Composite materials. Challenges in forming automotive materials.

Unit - III: Materials for Engines and Transmission Systems

Materials selection for IC engines: Material Selection criteria of Piston, piston rings, cylinder, Engine block, connecting rod, Crank shaft, Fly wheels, Gear box, Gears, and Clutches.

Unit - IV Materials for Automotive Structures

Materials selection criteria for bearings, leaf springs, chassis & frames, shock absorbers, brake shoes, and Disc.

Unit - V Electronic Materials for Automotive Applications

Materials for sensors and electronic devices meant for Engine Speed and Crank Position, Manifold Absolute Pressure, Temperature Sensor, Oxygen Sensor, Piezoelectric Sensor, Ultrasonic Sensor, and Dew Sensor. Sensor Materials and Technologies.

Suggested Readings:

1. Gladius Lewis, “Selection of Engineering Materials”, Prentice Hall Inc. New Jersey USA, 1995.
2. Hiroshi Yamagata,” The Science and Technology of Materials in Automotive Engines”, Woodhead Publishing,2005

Reference Books:

1. ASM Handbook. “Materials Selection and Design”, Vol. 20- ASM Metals Park Ohio.USA, 1997.
2. ASM Handbook, “Selection of Materials Vol. 1 and 2”, ASM Metals Park, Ohio. USA, 1991.
3. Cantor,“ Automotive Engineering: Lightweight, Functional, and Novel Materials”, Taylor & Francis Group, London, 2006
4. James A. Jacobs, Thomas F. Kilduff., “Engineering Materials Technology: Structure, Processing, Properties & Selection”, Prentice Hall, USA, 1996. 5. M F Ashby, “Materials Selection in Mechanical Design”, third edition, Butterworth- Heineman, New York, 2005.

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B.Tech in Metallurgical and Materials Engineering
VIII Semester Syllabus
(Professional Elective –VI)
MM816PE: Composite Materials

Course objective

- The prime objective of this course is to introduce, classify, and process composite materials which are novel and widely applied materials. The applications of composite materials that would suit the requirements are also dealt in detail as an integral part.

Course Outcomes

Through this course, the student will be able

- To understand the type bonds and structure of composite materials.
- To understand the mechanical and environmental behavior of composites inengineering applications.
- To understand the concepts of composites to design and apply for a specific application.
- To understand the manufacturing of different fibers, matrices, andapplications of Polymer matrix composites (PMCs), Metal MatrixComposites (MMCs), Ceramic Matrix Composites (CMCs) and Carbon-Carbon Composites (CCCs)

Unit - I: Introduction

Definition – Classification of Composite materials based on structure and matrix. Advantages and disadvantages application of composites based on structure – Functional requirements of reinforcement and matrix. Effect of reinforcement (size, shape, distribution, volume fraction) on overall composite performance.

Unit - II: Reinforcements

Preparation, properties and applications of glass fibers, carbon fibers, Kevlar fibers and Boron fibers. properties and applications of whiskers, particle reinforcements. Mechanical behaviour of composites; Rule of mixtures, Inverse rule of mixtures. Loading under Iso-strain and Iso-stress conditions.

Unit - III: Manufacturing of Polymer Matrix Composites (PMCs)

Preparation of Moulding compounds and prepregs – hand lay-up method – Autoclave method – Filament winding method – Compression moulding – Reaction injection moulding,Properties, and applications polymer composites

Unit - IV: Manufacturing of Metal Matrix Composites (MMCs)

Casting – Solid State diffusion technique, Cladding – Hot isostatic pressing. Liquid Metal Infiltration – Liquid phase sintering.Properties, and applications Metal Matrix composites.

Unit - V: Manufacturing of Ceramic Matrix Composites (CMCs) and (CCCs)

Manufacture of Ceramic Matrix Composites, Hot Pressing, Hot Iso Static Pressing, Sintering, Sinter/HIP, Spark Plasma Sintering, Manufacturing of Carbon – Carbon Composites; Knitting, Weaving. Braiding, Properties, and applications of Ceramic Matrix and Carbon-Carbon Composites

Suggested Readings:

1. Composite Materials – K.K.Chawla
2. Materials Science and Engineering, An introduction. WD Callister, Jr., Adapted by R. Balasubramanian, John Wiley & Sons, NY, Indian edition, 2007

Reference Books:

1. Handbook of Composites - George Lubin
2. Materials Science and Technology – Vol 13 – Composites by Cahn – VCH, West Germany
3. Composite Materials Science and Applications – Deborah D.L. Chung
4. Composite Materials: Design and Applications – Danial Gay, Suong V. Hoa, and Stephen W. Tsai