Department of Metallurgy and Materials Engineering

Indian Institute of Engineering Science and Technology Shibpur

# Course-Curriculum and Syllabi

## B.Tech. in Metallurgy and Materials Engineering

3rd Semester to 8th Semester

| Third (3rd) Semester: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Sl. No.** | **Course Name** | **Course Code** | **Class Load/Week** | | | **Credit** | **Class load per week** | **Marks** |
| | | | **L** | **T** | **P** | | | |
| 1 | Mathematics-III | MA21xx | 3 | 0 | 0 | 3 | 3 | 100 |
| 2 | (Core Theory – I) Metallurgical Thermodynamics | MM2101 | 3 | 1 | 0 | 4 | 4 | 100 |
| 3 | (Core Theory – II) Transport Phenomena and Rate Processes | MM2102 | 3 | 0 | 0 | 3 | 3 | 100 |
| 4 | (Core Theory – III) Physical Metallurgy of Ferrous Alloys | MM2103 | 3 | 0 | 0 | 3 | 3 | 100 |
| 5 | (Core Theory – IV) Physics of Materials | MM2104 | 3 | 0 | 0 | 3 | 3 | 100 |
| | **Theory Sub-Total** | | **15** | **1** | **0** | **16** | **16** | **500** |
| 6 | (Core Lab – I) Transport Phenomena and Rate Processes Lab. | MM2171 | 0 | 0 | 3 | 2 | 3 | 50 |
| 7 | (Core Lab –II) Physical Metallurgy Lab. | MM2172 | 0 | 0 | 3 | 2 | 3 | 50 |
| 8 | (Core Lab –III) Physics of Materials lab. | MM2173 | 0 | 0 | 3 | 2 | 3 | 50 |
| 9 | Mini Project | MM2191 | 0 | 0 | 0 | 2 | 0 | 50 |
| | **Sessional Sub-Total** | | **0** | **0** | **9** | **8** | **9** | **200** |
| | **3rd Semester Total** | | | | | **24** | **25** | **700** |

| Course Code | MM2101 | Course Name | Metallurgical Thermodynamics | Course Category | Core Theory | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 1 | 0 |

| Pre-requisite Courses | *NIL* | Co-requisite Courses | *NIL* | Progressive Courses | *NIL* |
|---|---|---|---|---|---|
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| Module | Syllabus | Duration (h) |
|---|---|---|
| *Module-I* | **Fundamental concepts in thermodynamics**: System, Surroundings, State, Extensive and Intensive properties and Heterogeneous systems, Internal energy, Heat capacity, Enthalpy, Isothermal and Isobaric processes | 4 |
| *Module-II* | **Laws of thermodynamics:** Entropy, Fugacity, Activity, Zeroeth, First, Second, Third laws and their applications | 5 |
| *Module-III* | **Free Energy** – Gibbs and Helmholtz Free Energy, Maxwell's Equations, Ellingham Diagram, Transformation Formula | 5 |
| *Module- IV* | **Equilibrium:** Concept of Equilibrium, Quasistatic Processes and Equilibrium constants, Equilibrium diagrams, Phase stability diagrams, stability of phases: intermetalic compounds and intermediate phases | 5 |
| *Module-V* | **Solutions:** Solutions and Partial molar quantities, Laws for ideal and non-ideal solutions, Concepts of standard states, thermodynamics of slags, basic concepts of ordered solution and some common types of ordering in alloys. | 6 |
| *Module-VI* | **Phase formation and stability**: Thermodynamics and theories of alloying, Phase rule applications, free-energy-composition diagrams and determination of liquidus, solidus and solvus lines, Spinodal Decomposition, Chemical Potential | 7 |
| *Module-VII* | **Thermal Analysis of Materials:** Differential Scanning Calorimetry, Thermogravimetric Analysis and Dilatometry | 5 |

| **Learning Resources** | i) Introduction to metallurgical thermodynamics by David R. Gaskell: Taylor & Francis<br>ii) Introduction to Materials and Metallurgical Thermodynamics by A. Ghosh published by PHI |
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| Course Code | MM2102 | Course Name | Transport Phenomena and Rate Processes | Course Category | Core Theory | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | | Co-requisite Courses | | *NIL* | Progressive Courses | *NIL* |
|---|---|---|---|---|---|---|
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* | |

| Module | Syllabus | Duration (h) |
|---|---|---|
| *Module-I* | **Introduction**: Homogeneous and heterogeneous reactions, Introductory concepts of kinetics of heterogeneous reactions, Concepts of rate controlling step and virtual maximum rate; Identification of reaction mechanisms | 4 |
| *Module-II* | **Kinetics of Homogeneous Chemical Reactions**: Law of mass action, Integrated Rate Equations, Variation of rate constant with temperature, Arrhenius equation, Theory of Absolute Reaction Rates | 4 |
| *Module-III* | **Gas-Solid and Gas-Liquid Interfacial Reactions**: Adsorption, Adsorption Isotherms, Examples of slow surface reactions in high temperature metallurgy | 6 |
| *Module-IV* | **Momentum Transport**: Newton's law of viscosity, Shell momentum balance, Concepts of Laminar and Turbulent flow, Friction factor | 8 |
| *Module-V* | **Energy Transport**: Fourier's law of heat conduction, Theories of thermal conductivity, Shell Energy Balances and Temepearture Distribution in Solids | 8 |
| *Module-VI* | **Mass Transport**: Steady and unsteady diffusion, Fick's laws of diffusion, Applications of diffusion equations in metallurgy, Diffusion: Fick's laws-their solution and application: Atomic mechanism of different kinds of diffusion, kirkendall effects, uphill diffusion. | 6 |
| *Module-VII* | **Kinetics of Reactions of Porous Solids with Gases:** Diffusion of gases through porous solids, Kinetics of reduction of oxides by gases, Kinetics of gasification of carbon by carbon dioxide, Kinetics of reduction of iron oxide by carbon | 6 |

| Learning Resources | |
|---|---|
| | 1. D. R. Poirier, G. H. Geiger, Wiley, "Transport Phenomena in Materials Processing".<br>2. A. Ghosh, S. Ghosh, S. (2014), Phi Learning Pvt. Ltd. "A textbook of metallurgical kinetics"<br>3. R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot. Wiley International edition, "Transport Phenomena".<br>4. Julian Szekely, Academic Press, University of Michigan, "Fluid flow phenomena in metals processing"<br>5. P.G. Shewmon, 2nd Edition, 1991, John Wiley and Sons, "Diffusion in solids" |

| Course Code | MM2103 | Course Name | Physical Metallurgy of Ferrous Alloys | Course Category | Core Theory | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | | Co-requisite Courses | | Progressive Courses | *NIL* |
|---|---|---|---|---|---|
| Course Offering Department | | *Metallurgy and Materials Engineering* | | Data Book / Codes/Standards | *NIL* |

| Module | Syllabus | Duration (h) |
|---|---|---|
| *Module-I* | Introduction and classification of phase transformations | 2 |
| *Module-II* | **Principles of heat treatment of steels**<br>Fe-Fe3C diagram; Formation of austenite - kinetics and mechanism; Grain growth and size of austenite grain; Homogeneity of austenite, Selection of austenitizing temperature and time. | 4 |
| *Module-III* | **Phase transformation in steels**<br>Thermodynamics, Kinetics and Mechanisms of ferritic, pearlitic, Bainitic and Martensitic Transformations. | 8 |
| *Module-IV* | Crystal structure and atomic arrangement in solids: Defects in crystals: dimension, origin and their effects on properties; concepts of grains, grain boundaries and texture. (in more detail: Poiint group, Space group, Symmetry Elements) | 6 |
| *Module-V* | Construction, interpretation of different types of equilibrium phase diagrams. Interpretation of ternary equilibrium phase diagrams. Description of some important equilibrium phase diagrams e.g. metal-nonmetal, metal-metal, ceramic-ceramic etc. | 8 |
| *Module-VI* | Solidification of metals and alloys; thermal and constitutional super-cooling, cooling curves, coring and micro/macro segregations. | 6 |
| *Module-VI* | Optical microscopy: principles of different techniques, specimen preparation, Principles of various temperature measurement techniques. Thermal analysis measurement techniques. | 4 |
| *Module-VII* | Significance of structure-properties-processing relationship of engineering materials | 4 |

| Learning Resources | 1. Physical Metallurgy, Robert W. Cahn and Peter Haasen<br>2. Physical Metallurgy and Advanced Materials, R. E. Smallman and A.H.W. Ngan<br>3. Modern Physical Metallurgy and Materials Engineering, R. E. Smallman and R. J. Bishop<br>4. Physical Metallurgy Principles, Robert E. Reed-Hill<br>5. Physical Metallurgy, Vijendra Singh |
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| Course Code | MM2104 | Course Name | Physics of Materials | Course Category | Core Theory | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | | Co-requisite Courses | | *NIL* | Progressive Courses | *NIL* |
|---|---|---|---|---|---|---|
| Course Offering Department | | ***Metallurgy and Materials Engineering*** | | Data Book / Codes/Standards | *NIL* | |

| Module | Syllabus | Duration (h) |
|---|---|---|
| *Module-I* | **Electron theory of metals**: de Broglie waves, uncertainty principle, Drude's Theory, wave function and Schrodinger equation; Free electron theory, concepts of density of states, probability interpretation, particle on a chain, potential barrier and quantum tunneling, potential well, qualitative summary of simple harmonic oscillation and Hydrogen atom. Occupation probability and examples. | 7 |
| *Module-II* | **Zone theory**: Brillouin zone, free electron band diagrams, potential in a crystal, electron dynamics and concept of holes, conductivity in relation to band structure, band structure of metals, semiconductors and insulators; direct and indirect band-gap semiconductors, intrinsic and extrinsic semiconductors. Ionic conduction - review of defect equilibrium and diffusion mechanisms, theory of ionic conduction, conduction in glasses, effect of stoichiometric and extrinsic defects on conduction, applications in sensors and batteries. | 7 |
| *Module-III* | **Dielectric materials**: Dielectric constant and polarization, linear dielectric materials, capacitors and insulators, polarization mechanism, non-linear dielectrics – pyro-, piezo and ferro-electric thermo-electric properties, hysteresis and ferro-electric domains and applications. | 7 |
| *Module- IV* | **Optical materials**: electron-hole recombination, solid-state LED's, Lasers and IR detectors, band gap engineering; Light interaction with materials – transparency, translucency and opacity, refraction and refractive index; reflection, absorption and transmission. | 7 |
| *Module-V* | Magnetic field, flux density, susceptibility and permeability; Orbital and spin, permanent magnetic moment of atoms, diamagnetism, paramagnetism and pauli paramagnetism, ferro-, anti-ferro and ferri- magnetism, Fe, Co, Ni and alloy additions, ferrites, magnetic hysteresis, soft and hard magnetic materials. | 7 |
| *Module-VI* | Superconductivity | 2 |

| **Learning Resources** | Physics of Materials: Essential Concepts of Solid-State Physics, Prathap Haridoss, Wiley (2015)<br>Physics of Materials, 1st Edition, Y. Quere CRC Press (1998)<br>Solid State Physics, 2nd edition, J.S. Blakemore, Cambridge University Press (1985) |
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| **Course Code** | MM2171 | **Course Name** | Transport Phenomena and Rate Processes Lab. | **Course Category** | Core Lab | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 0 | 0 | 3 |

| **Pre-requisite Courses** | *NIL* | **Co-requisite Courses** | *NIL* | **Progressive Courses** | *NIL* |
|---|---|---|---|---|---|
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| **Module** | **Syllabus** | **Duration (h)** |
|---|---|---|
| *Module-I* | Estimation of activation energy | 6 |
| *Module-II* | Diffusion kinetics | 6 |
| *Module-III* | Oxidation of metals: Study of kinetics of oxidation of various metal samples at different temperatures | 6 |
| *Module- IV* | Kinetics of mixing | 6 |
| *Module-V* | Kinetics of direct reduction | 6 |
| *Module-VI* | Cementation kinetics | 6 |

| **Learning Resources** | • Metallurgical Thermodynamics Kinetics by S. K. Dutta and A. B. Lele, S Chand and Company Limited, New Delhi<br>• A Text Book of Metallurgical Kinetics by A. Ghosh and S. Ghosh, PHI Learning Private Limited<br>• A first Course on Iron and Steelmaking, by D. Mazumdar, Universities Press – IIM<br>• Kinetics of Metallurgical Reactions by H. S. Ray, Oxford & IBH publishing Co. Pvt. Ltd<br>• Heat and Mass Transfer by R. K. Rajput, S Chand and Company Limited, New Delhi |
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| **Course Code** | MM2172 | **Course Name** | Physical Metallurgy Laboratory | **Course Category** | Core Lab | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 0 | 0 | 3 |

| **Pre-requisite Courses** | | **Co-requisite Courses** | Physical Metallurgy | **Progressive Courses** | *NIL* |
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| **Course Offering Department** | ***Metallurgy and Materials Engineering*** | **Data Book / Codes/Standards** | *NIL* |

| **Module** | **Syllabus** | **Duration (h)** |
|---|---|---|
| **Module** | **Syllabus** | **Duration (h)** |
| *Module-I* | Preparation of scratch free samples and demonstration of optical microscopes | 3 |
| *Module-II* | Evaluation of inclusion rating of scratch free samples | 3 |
| *Module-III* | Study of microstructure of Armco Iron and IF steel | 3 |
| *Module-IV* | Study of microstructure of 0.3 wt% C steel annealed, normalized, oil quenched, and water quenched from 900˚C | 3 |
| *Module-V* | Study of microstructure of 0.5 wt% C steel annealed, normalized, oil quenched, and water quenched from 850˚C | 3 |
| *Module-VI* | Study of microstructure of 0.8 wt% C steel annealed, normalized, oil quenched, and water quenched from 850˚C | 3 |
| *Module-VII* | Study of microstructure of 1.1 wt% C steel annealed, normalized, oil quenched, and water quenched from 850˚C | 3 |
| *Module-VIII* | Study of Microstructure of various types cast iron | 3 |
| *Module-IX* | Evaluation of microstructure and macrostructure of annealed Cu, Al, Mg, Zn etc. | 3 |
| *Module-X* | Evaluation of microstructure and macrostructure of Ti and Ti based alloys | 3 |
| *Module-XI* | Study of microstructure of different types of brasses (Cu-30Zn and Cu-40Zn) and bronzes (tin bronze, P bronze, Al bronze) | 3 |
| *Module-XII* | Recovery, recrystallization and grain growth of deformed Cu | 3 |
| *Module-XIII* | Identification of unknown samples | 3 |

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| **Learning Resources** | |

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| **Course Code** | MM2173 | **Course Name** | Physics of Materials | **Course Category** | Core Lab | L | T | P |
| | | | | | | 0 | 0 | 3 |

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| | | | Laboratory | | | | | |

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| **Pre-requisite Courses** | | **Co-requisite Courses** | Physics of Materials | **Progressive Courses** | *NIL* |
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| **Module** | **Syllabus** | **Duration (h)** |
|---|---|---|
| *Module-I* | Atomic Packing: Model (Software: VESTA) | 3 |
| *Module-II* | Crystal Structure determination using X-rays | 3 |
| *Module-III* | Concept of diffraction and reciprocal lattice and stereographic projection | 6 |
| *Module-IV* | SEM orientation: Electron-Matter interaction outcome | 3 |
| *Module-V* | Resistivity and conductivity measurement | 6 |
| *Module-VI* | Determination of bandap | 3 |
| *Module-VII* | Determination of electrical mobility from transistor I-V characteristic | 3 |
| *Module-VIII* | Measurement of dielectric properties: Determination of dielectric constant, relaxation time, analysis of Nyquist plot | 6 |
| *Module-IX* | Case Studies and problem solving: Identification of different physics involved in some practical problems and approach towards solving the problem related to materials engineering | 9 |

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| **Learning Resources** | |

| **Course Code** | MM2205 | **Course Name** | Principles of Extractive Metallurgy | **Course Category** | Core Theory | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

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| **Pre-requisite Courses** | *NIL* | **Co-requisite Courses** | *NIL* | **Progressive Courses** | *NIL* |
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| Module | Syllabus | Duration (h) |
|---|---|---|
| *Module-I* | **Introduction**: Important ores and minerals and their occurrence in India; Importance of mineral-dressing | 2 |
| *Module-II* | **Mineral dressing**: Various Comminution Processes - theories involved, brief description and applications, various concentration techniques and their applications, mineral dressing circuits and flowsheets | 8 |
| *Module-III* | **Unit Processes in Pyrometallurgy**: Introduction, Calcination, Roasting, Agglomeration, Reduction smelting, Matte smelting, Flash smelting, and Converting | 12 |
| *Module- IV* | **Unit Processes in Hydrometallurgy**: Introduction, Leaching, Purification of Leach Liquor, Solvent Extraction and Ion-exchange Processes, Techniques of Metal Recovery from Aqueous phase | 6 |
| *Module-V* | **Unit Processes in Electrometallurgy**: Introduction, Faraday's laws of electrolysis, concept of overvoltage, limiting current density, Electrowinning and Electro-refining with reference to copper, zinc and aluminium | 6 |
| *Module-VI* | **Flowsheets and numerical calculations**: Flow-charts, Material balance and Heat balance | 2 |

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| **Learning Resources** | 1. Principles of Extractive Metallurgy - A. Ghosh, and H. S. Ray<br>2. Non-ferrous Extractive Metallurgy - H. S. Ray, R. Sridhar and K. C. Abraham<br>3. Extractive Metallurgy Principles - T. Rosenqvist<br>4. Extractive Metallurgy - J. Gilchrist |

| Fourth (4th) Semester: | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Sl. No.** | **Course Name** | **Course Code** | **Class Load/Week** | | | **Credit** | **Class load per week** | **Marks** |
| | | | **L** | **T** | **P** | | | |
| 1 | (Core Theory – V) Principles of Extractive Metallurgy | MM2205 | 3 | 0 | 0 | 3 | 3 | 100 |
| 2 | (Core Theory – VI) Heat Treatment | MM2206 | 3 | 1 | 0 | 4 | 4 | 100 |
| 3 | (Core Theory – VII) Deformation Behaviour of Materials | MM2207 | 3 | 0 | 0 | 3 | 3 | 100 |
| 4 | (Core Theory – VIII) Computational Materials Engineering | MM2208 | 3 | 0 | 0 | 3 | 3 | 100 |
| 5 | (Core Theory – IX) Iron Making | MM2209 | 3 | 0 | 0 | 3 | 3 | 100 |
| | **Theory Sub-Total** | | **15** | **1** | **0** | **16** | **16** | **500** |
| 6 | (Core Lab – IV) Extractive Metallurgy Lab. | MM2274 | 0 | 0 | 3 | 2 | 3 | 50 |
| 7 | (Core Lab – V) Heat Treatment Lab. | MM2275 | 0 | 0 | 3 | 2 | 3 | 50 |
| 8 | (Core Lab – VI) Deformation Behaviour of Materials Lab. | MM2276 | 0 | 0 | 3 | 2 | 3 | 50 |
| 9 | (Core Lab-VII) Computational Materials Engineering Lab. | MM2277 | 0 | 0 | 3 | 2 | 0 | 50 |
| | **Sessional Sub-Total** | | **0** | **0** | **12** | **8** | **9** | **200** |
| | **3rd Semester Total** | | | | | **24** | **25** | **700** |

| **Course Code** | MM2205 | **Course Name** | Principles of Extractive Metallurgy | **Course Category** | Core Theory | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| **Pre-requisite Courses** | *NIL* | **Co-requisite Courses** | *NIL* | **Progressive Courses** | *NIL* |
|---|---|---|---|---|---|
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| **Module** | **Syllabus** | **Duration (h)** |
|---|---|---|

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|---|---|---|
| *Module-I* | **Introduction**: Important ores and minerals and their occurrence in India; Importance of mineral-dressing | 2 |
| *Module-II* | **Mineral dressing**: Various Comminution Processes - theories involved, brief description and applications, various concentration techniques and their applications, mineral dressing circuits and flowsheets | 8 |
| *Module-III* | **Unit Processes in Pyrometallurgy**: Introduction, Calcination, Roasting, Agglomeration, Reduction smelting, Matte smelting, Flash smelting, and Converting | 12 |
| *Module- IV* | **Unit Processes in Hydrometallurgy**: Introduction, Leaching, Purification of Leach Liquor, Solvent Extraction and Ion-exchange Processes, Techniques of Metal Recovery from Aqueous phase | 6 |
| *Module-V* | **Unit Processes in Electrometallurgy**: Introduction, Faraday's laws of electrolysis, concept of overvoltage, limiting current density, Electrowinning and Electro-refining with reference to copper, zinc and aluminium | 6 |
| *Module-VI* | **Flowsheets and numerical calculations**: Flow-charts, Material balance and Heat balance | 2 |

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|---|---|
| **Learning Resources** | 1. Principles of Extractive Metallurgy - A. Ghosh, and H. S. Ray<br>2. Non-ferrous Extractive Metallurgy - H. S. Ray, R. Sridhar and K. C. Abraham<br>3. Extractive Metallurgy Principles - T. Rosenqvist<br>4. Extractive Metallurgy - J. Gilchrist |

| **Course Code** | **MM2206** | **Course Name** | **Heat Treatment** | **Course Category** | Core Theory | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | **3** | **1** | **0** |

| **Pre-requisite Courses** | *Nil* | **Co-requisite Courses** | *Nil* | **Progressive Courses** | *NIL* |
|---|---|---|---|---|---|
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| **Module** | **Syllabus** | **Duration (h)** |
|---|---|---|
| *Module-I* | **Introduction and classification of heat treatment processes**<br>Various annealing, Normalizing, Hardening and Tempering treatments; Heat treatment-Microstructure-Property correlations. | 8 |

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| *Module- II* | **TTT and CCT diagrams**<br>Construction and utility of T-T-T and C-C-T diagrams, Critical cooling rate, Factors affect the T-T-T and C-C-T diagrams; Effect of Alloying elements. | 6 |
| *Module-III* | **Hardenability**<br>Significance, Critical and ideal critical diameter, Jominy End Quench method, Factors affecting hardenability. Characteristics of quenchants, Different quenching media. Development of residual stresses, Quench cracking. | 6 |
| *Module-IV* | **Thermo-mechanical treatments**<br>Principles and processes- austempering, martempering, patenting, ausforming etc. HSLA steels and rebars. | 6 |
| *Module-V* | **Heat treatment of different types of steels**<br>Classifications, Role of major alloying elements, heat treatment process and microstructural changes; Retained austenite, Sub-zero treatment | 3 |
| *Module-VI* | **Surface hardening of steels**<br>Classification, Principles, Case carburizing (solid, liquid and gas), Nitriding, Cyaniding, Carbonitriding, Plasma nitriding, Selective hardening, Flame hardening, Induction hardening, Laser hardening etc. Measurement of case depth and its relation with time and temperature. | 4 |
| *Module-VII* | **Design for heat treatment**<br>Heat treatment furnaces- their temperature and atmosphere control; Defects in heat treated parts - Causes and remedies; Automation. | 2 |

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| **Course Code** | MM2207 | **Course Name** | Deformation Behaviour of Materials | **Course Category** | Core-Theory | L | T | P |
| | | | | | | 3 | 0 | 0 |

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| **Pre-requisite Courses** | | **Co-requisite Courses** | *NIL* | **Progressive Courses** | *NIL* |
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | **Data Book / Codes/Standards** | *NIL* | |

| **Module** | **Syllabus** | **Duration (h)** |
|---|---|---|
| *Module-I* | **Introduction to deformation behaviour:** Concept of stresses and strains; engineering and true stress/strain; analysis of simple tension test data | 6 |
| *Module-II* | **Theory of Elasticity:** State of stress at a point, State of plane stress, Principal stresses and planes, Mohr's circle of stress (2D), State of stress in 3D; Strain at a point: Definition of normal and shear strains; Concept of hydrostatic stress and stress deviator; Elastic stress-strain relationships; Elastic strain energy | 6 |

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| *Module-III* | **Theory of Plasticity:** Flow Curve, power-law erelationship; Relationship between true stress and engineering stress; Yield criteria for ductile metals: Von Mises' criterion and Tresca criterion; Combined stress tests; Yield locus; Octahedral shear stress and shear strain; Invariants of stress and strain; Plastic stess-strain relationships: Levy-Mises equations and Prandtl-Reuss equations | 8 |
| *Module-IV* | **Plastic deformation of a single crystal:** Review of crystal planes and directions; Point defects; Line defects; Deformation by slip; Critically Resolved Shear Stress; Deformation by twinning; Stacking faults; Generalized flow curve for a FCC single crystal | 6 |
| *Module-V* | **Dislocation theory**: Edge, screw and mixed dislocations; Burgers vector and Burgers circuit; Peierl-Nabarro stress; Cross-slip of screw dislocations; Dislocation reactions; Dislocations in FCC lattice:Partial disloactions, Lomer-Cottrell barrier; Dislocations in HCP lattice and in BCC lattice; Stress-field of dislocations; Elastic strain energy of dislocations; Force between dislocations; Dislocation climb; Intersection of Dislocations; Sources of dislocations; Multiplication of dislocations; Interaction between adislocation and a point defect | 8 |
| *Module-VI* | **Strengthening Mechanisms**: Grain boundaries; Equi-chesive temperature; Hall-Petch relationship; Yield Point phenomenon; Strain-aging; Solid-sloution strengthening; Strenthening from fine particles: Age hardening; Fibre strengthening; Martensite strengthening; Ausforming; Strain hardening: cold-worked structure; Effect of annealing on cold-worked metal; Bauschinger effect | 8 |

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| **Learning Resources** | 1. G.E. Dieter: Mechanical metallurgy, McGraw Hill Book Company, New Delhi, 1986.<br>2. J.N. Harris: Mechanical Working of Metals- Theory and Practice, Pergamon Press, Oxford, 1983.<br>3. J. Lin, D. Balint, M. Pietrzyk: Microstructure evolution in metal-forming processes, Woodhead Publishing Limited, 2012.<br>4. W. F. Hosford and R. M.Caddell: Metal Forming: Mechanics and Metallurgy, Prentice-Hall, 2011.<br>5. A.S.M. Handbook Vol. 14, Forming and Forging, ASM International<br>6. J. G. Lenard, Metal Forming Science and Practice, Elsevier Science Ltd., U.K, 2002 |

| Course Code | MM2208 | Course Name | Computational Materials Engineering | Course Category | Core Theory | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 3 | 0 | 0 |

| Pre-requisite Courses | *NIL* | Co-requisite Courses | *NIL* | Progressive Courses | *NIL* |
|---|---|---|---|---|---|
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| Module | Syllabus | Duration (h) |
|---|---|---|
| *Module-I* | Need of Computational Materials Engineering: Examples of challenges in design of materials for challenging applications, bottleneck areas of materials technology, introduction to the Integrated Computational Materials Engineering (ICME) approach. | 5 |
| *Module-II* | Atomistic schemes in Computational Materials Engineering: Introduction to basics of statistical mechanics, basics of molecular dynamics simulation, application of molecular dynamics for property prediction, basics of Monte Carlo approach and its application for modelling materials properties. | 12 |
| *Module-III* | Prediction of thermodynamic properties of materials:<br>Application of CALPHAD type approaches for prediction of phase diagrams and introduction to recent algorithms using atomistic simulations. | 6 |
| *Module-IV* | Mesoscale methods in materials science:<br>Quantification of microstructure: Application of Monte Carlo and Cellular Automata method for generation of microstructure, Introduction to Phase Field Method and Finite Element Method. | 7 |
| *Module-V* | Basics of Multiscale Modelling involving development of method for improved structure-property correlation:<br>Basics of bridging schemes in multiscale models. | 5 |
| *Module-VI* | Machine Learning in Materials Science: Introduction to Machine Learning, Data Pre-processing, Supervised Learning Algorithms including Artificial Neural Networks, Linear Regression, and Bayesian classification and Hidden Markov Models, Unsupervised Learning Algorithms, Optimisation techniques, Evolutionary algorithms. | 5 |

| **Learning Resources** | 1. Computational Materials Engineering: An Introduction to Microstructure Evolution, KGF Janssens, D. Raabe, E. Kozeschnik, M. Miodownik, B. Nestler, Academic Press.<br>2. Statistical mechanics: A survival guide, A. M. Glazer and J. S. Wark, Oxford University Press.<br>3. Integrated Computational Materials Engineering (ICME) for Metals: Using multiscale modelling to invigorate engineering design with science, M.E. Horstemeyer, Wiley.<br>4. Machine Learning, Anuradha Srinivasaraghavan, Vincy Joseph, Wiley.<br>5. Deep Learning using Python, S. Lovelyn Rose, L. Ashok Kumar, D. Karthika Renuka, Wiley |
|---|---|

| Course Code | MM2274 | Course Name | Extractive Metallurgy Lab. | Course Category | Core Lab | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 0 | 0 | 3 |

| Pre-requisite Courses | *NIL* | Co-requisite Courses | Principles of Extractive Metallurgy | Progressive Courses | *NIL* |
|---|---|---|---|---|---|
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| Module | Syllabus | Duration (h) |
|---|---|---|
| *Module-I* | Assignment on comminution of ore-crushing and grinding circuit, major equipment used, open circuit and close circuit | 3 |
| *Module-II* | Study of design and operation of primary crushing equipment (i) Jaw crusher and (ii) Gyratory crusher | 6 |
| *Module-III* | Study of design and operation of secondary crushing equipment: (i) Roll crusher and (ii) Cone crusher | 3 |
| *Module-IV* | Study of design and operation of grinding equipment - (i) Ball mill | 3 |
| *Module-V* | Study of design and operation of Wilflay table | 3 |
| *Module-VI* | Sieve Analysis of Particles: Plotting of Cumulative Curve | 6 |
| *Module-VII* | Study of kinetics of cementation of copper from aqueous solutions by zinc, and iron | 3 |
| *Module-VIII* | Study of kinetics of leaching of oxide metals in dilute acidic solutions | 3 |

| **Learning Resources** | • Process selection in Extractive Metallurgy by Peter Hayes, SBA Pulications<br>• Principles of Extractive Metallurgy, Vol.1 by Fathi Habashi, , Gordon and Breach, New York<br>• Principles of Mineral Dressing by A. M. Gaudin, McGrew Hill Book Company<br>• Mineral Processing by S. K. Jain, CBS publishers and Distributors Pvt. Ltd |
|---|---|

| Course Code | MM2275 | Course Name | Heat Treatment Laboratory | Course Category | | L | T | P |
|---|---|---|---|---|---|---|---|---|
| | | | | | | **0** | **0** | **3** |

| Pre-requisite Courses | Physical Metallurgy of Ferrous Alloys | Co-requisite Courses | Heat Treatment | Progressive Courses | *NIL* |
|---|---|---|---|---|---|
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | **ASTM Standards** |

| Module | Syllabus | Duration (h) |
|---|---|---|
| *Module-I* | **Heat Treatment Furnaces**<br>*Types, Construction, Circuit diagram* | 3 |

| | | |
|---|---|---|
| *Module-II* | **Operation and Control of Heat Treatment Furnaces** | 3 |
| *Module-III* | **Thermocouple Calibration** | 3 |
| *Module-IV* | **Effect of carbon content (0.3, 0.55, 0.8 and 1.1 wt.%) on microstructure and hardness of plain carbon steels** | 3 |
| *Module-V* | **Effects of cooling rate (annealing, normalizing, oil quenching and water quenching) on microstructure and hardness of eutectoid steel** | 3 |
| *Module-VI* | **Jominy End Quench Test** | 3 |
| *Module-VII* | **Effects of time and temperature on tempering of alloy steels** | 3 |
| *Module-VIII* | **Malleablizing heat treatment of white cast iron** | 3 |
| *Module-IX* | **Heat treatment of high speed steel** | 3 |
| *Module-X* | **Case hardening treatment** | 3 |
| *Module-XI* | **Microstructure and hardness evaluation of TMT rebar** | 3 |
| *Module-XII* | **Viva Voce** | 3 |

| | |
|---|---|
| **Learning Resources** | **1. Testing of Engineering Materials,** H.E. Davis, G.E. Troxell, G.F.W. Hauck, 4th Ed., McGrew Hill.<br>**2.ASM Handbook Volume 8: Mechanical Testing and Evaluation,** H. Kuhn, D. Medin (Ed.), ASM International.<br>**3. Practical Non-Destructive Testing,** B. Raj, T. Jayakumar, M. Thavasimuthu, Norasa. |

| | | | | | | L | T | P |
|---|---|---|---|---|---|---|---|---|
| **Course Code** | MM2276 | **Course Name** | Deformation Behaviour of Materials Laboratory | **Course Category** | Core Elective | 0 | 0 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| **Pre-requisite Courses** | *NIL* | **Co-requisite Courses** | Deformation Behaviour of Materials | **Progressive Courses** | *NIL* |
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| Module | Syllabus | Duration (h) |
|---|---|---|

| | | |
|---|---|---|
| *Module-I* | Introduction to basics of MATLAB / Python | 3 |
| *Module-II* | Analysis of tensile test data to evaluate elastic modulus, 0.2% yield strength, ultimate tensile strength and fracture strength of metals {using Microsoft Excel / MATLAB / Python} | 3 |
| *Module-II* | Analysis of tensile test data to evaluate strength coefficient, and strain-hardening coefficient, assuming power-law strain-hardening {using Microsoft Excel / MATLAB / Python} | 3 |
| *Module-III* | Analysis of two-dimensional state of stress (plane stress): Transformation of stresses, evaluation of principal stresses, principal directions, maximum shear stress, angle of plane for maximum shear stress;<br>Construction of Mohr's circle of stress – two dimensions {using MATLAB / Python} | 3 |
| *Module-IV* | Analysis of three-dimensional state of stress: Evaluation of invariants of stress, principal normal stresses and corresponding principal directions, principal shear stress, hydrostatic stress, deviatoric stress, $J_2$<br>Construction of Mohr's circle of stress – three dimensions<br>{using MATLAB / Python} | 3 |
| *Module-V* | Analysis of three-dimensional state of strain: Evaluation of strain tensor and rotation tensor from a given displacement vector, evaluation of volumetric strain, hydrostatic strain, strain deviator {using MATLAB / Python} | 3 |
| *Module- VI* | Evaluation of elastic strains from elastic stresses and vice-versa for isotropic elastic solids; evaluation of shear modulus and bulk modulus; evaluation of elastic strain energy {using MATLAB / Python} | 3 |
| *Module-VII* | Finite Element simulation of elastic deformation {using COMSOL Multiphysics/ABAQUS} | 3 |
| *Module-VIII* | Evaluation of yielding criteria of ductile metals using Von Mises' and Tresca criteria; Construction of yield locus for a biaxial state of stress | 3 |
| *Module--IX* | Finite Element simulation of elasto-plastic deformation {using COMSOL Multiphysics/ABAQUS} | 3 |
| *Module-X* | Generation of crystal structures and development of understanding of dislocations in various crystal structures (FCC, BCC and HCP). Visualization of dislocations (edge and screw) using ATOMSK code. | 3 |
| *Module-XI* | Study of dislocation-solute interaction in representative alloy systems. Stress fields around dislocation (Volterra dislocations). Study of dislocation stress-field and solute misfit and its ultimate effect on the strength of metallic systems. | 6 |
| *Module-XII* | Viva-Voce | 3 |

| | |
|---|---|
| **Learning Resources** | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Course Code** | MM2277 | **Course Name** | Computational Materials Engineering Laboratory | **Course Category** | Core Lab | L | T | P |
| | | | | | | 0 | 0 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| **Pre-requisit** | | **Co-requisite** | Computational Materials Engineering | **Progressive Courses** | *NIL* |

| | | | | | |
|---|---|---|---|---|---|
| **e Courses** | | **Course s** | | | |
| **Course Offering Department** | | ***Metallurgy and Materials Engineering*** | | **Data Book / Codes/Standards** | *NIL* |

| **Module** | **Syllabus** | **Duration (h)** |
|---|---|---|
| *Module-I* | Introduction to Integrated Computational Materials Engineering for structure-property correlation. | 3 |
| *Module-II* | Introduction to Atomistic Simulation Environment and basics of Python programming. | 3 |
| *Module-III* | Application of statistical mechanics-based tools for determination of thermodynamic properties such as specific heat capacity, enthalpy and free energy. | 3 |
| *Module-IV* | Molecular dynamics of elemental metals and binary alloys to study the phase stability. | 3 |
| *Module-V* | Monte Carlo based microstructure generation-studying grain growth phenomena. | 3 |
| *Module-VI* | Cellular Automata based microstructure design studies. | 3 |
| *Module-VII* | Using COMSOL to simulate any one of the multi-physics phenomena (Induction heating of steel slab, Cooling or solidification of steel, continuous casting, multiscale 3D packed reactor, localised corrosion, anodization of Al). | 3 |
| *Module-VIII* | Using ANSYS to simulate steelmaking processes: Creation of geometry, computational mesh generation, formulation of models, turbulence models, etc. | 3 |
| *Module-iX* | Application of ANSYS to simulate metal forming processes. | 3 |
| *Module-X* | Application for machine learning based approaches for microstructure identification (e.g., Deep Learning approaches in image analysis). | 3 |

| | |
|---|---|
| **Learning Resources** | 1. Computational Materials Engineering: An Introduction to Microstructure Evolution, KGF Janssens, D. Raabe, E. Kozeschnik, M. Miodownik, B. Nestler, Academic Press.<br>2. Statistical mechanics: A survival guide, A. M. Glazer and J. S. Wark, Oxford University Press.<br>3. Integrated Computational Materials Engineering (ICME) for Metals: Using multiscale modelling to invigorate engineering design with science, M.E. Horstemeyer, Wiley.<br>4. Machine Learning, Anuradha Srinivasaraghavan, Vincy Joseph, Wiley.<br>5. Deep Learning using Python, S. Lovelyn Rose, L. Ashok Kumar, D. Karthika Renuka, Wiley |

**5th Semester:**

| Sl. No | Course Name | Course code | Class Load/Week | | | Credit | Class load/ week |
|---|---|---|---|---|---|---|---|
| | | | L | T | P | | |
| 1. | Economics/ Polymer and Refractory Technology | HU5601/ CH501 | 2/2 | 1/1 | 0 | 3/3 | 3/3 |
| 2. | Iron and Steel Making | MT501 | 3 | 1 | 0 | 4 | 4 |
| 3. | X-Ray and Electron Diffraction | MT502 | 3 | 1 | 0 | 4 | 4 |
| 4. | Metal Casting Technology | MT503 | 3 | 1 | 0 | 4 | 4 |
| 5. | Heat Treatment Technology | MT504 | 2 | 1 | 0 | 3 | 3 |
| 6. | EL I (OE): Environmental issues in Metallurgical Industries | MT505 | 3 | 0 | 0 | 3 | 3 |
| | Theory Sub-total | | 16/16 | 5/5 | 0 | 21/21 | 21/21 |
| 7. | Metal Casting Technology Lab | MT551 | 0 | 0 | 3 | 2 | 3 |
| 8. | X-Ray and Electron Diffraction Lab | MT552 | 0 | 0 | 2 | 1 | 2 |
| 9. | Heat Treatment Technology Lab | MT553 | 0 | 0 | 3 | 2 | 3 |
| | Sessional Sub-total | | 0 | 0 | 8 | 5 | 8 |
| | 5th Semester Total | | | | | 26/26 | 29/29 |

**MT 501: Iron and Steel Making** **3-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Introduction: Raw materials used for iron making and their availability in India. Characteristics of suitable raw materials. Blast furnace (BF) iron making- design features of BF and supporting units, viz. Coke ovens, Stoves, gas cleaning systems | 03 |
| 2. | Up gradation of raw materials: Washing of ore & coal; Agglomeration of iron ores – process control and current innovations. | 02 |
| 3. | Reduction mechanism and equilibrium in carbon-oxygen system; slag formation, chemistry and characteristics; Reserve Zones, Cohesive Zone and their importance. | 06 |
| 4. | Modern trends to minimize coke rate and emissions Injection techniques; Blast furnace (BF) irregularities and remedies. Treatment of slag and outgoing gas. | 03 |
| 5. | Automation and Instrumentation; Treatment of hot metal outside BF. | 03 |
| 6. | Alternate routes of Iron making - Direct reduced iron (DRI); Gas based and Coal-based DRI; Hot briquetted iron (HBI); Problems and prospects of DRI in India. | 05 |
| 7. | Steel making: Historical perspective and current scenario; Principles of refining, Steel making in Basic Oxygen Converters, kinetics of reactions; brief overview of various techniques of Top-blown, Bottom-blown and Combined-blown BOF; lance design, slag characteristics | 04 |
| 8. | Arc furnace steel making - production of alloy steels; Induction furnace steel making: Use of DRI in steel making. | 03 |
| 9. | Secondary steel making - Quality, de-oxidation and de-sulphurization; Vacuum techniques- remelting and refining; Injection Metallurgy. | 03 |

| | | |
|---|---|---|
| 10. | Inclusion removal and its modification. Casting of ingots and continuous casting. Defects and remedies. | 04 |
| 11. | Energy and Environmental aspects in steel making, concept of zero $CO_2$ emission. | 02 |
| 12. | Latest developments in steel making processes. | 03 |
| 13. | Principles of Ferro-alloys production - Application of Submerged Arc furnace; Brief description on production of Ferromanganese, Ferrosilicon, Ferrochrome etc. Application of Thermit reduction process, Preparation of special Ferro-alloys and their applications. | 03 |
| | Total | 44 |

**Suggested Reading:**

1. An Introduction to Modern Iron Making - R. H. Tupkary
2. An Introduction to Modern Steel Making - R. H. Tupkary
3. Principles of Blast Furnace Ironmaking: Theory and Practice - A. K. Biswas
4. Ironmking and Steelmaking: Theory and Practice - Ahindra Ghosh and Amit Chatterjee

**MT 502: X-Ray and Electron Diffraction** **3-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Fundamentals of diffraction- Electron-electron interaction, electron-atom interaction, electron-crystal interaction. | 04 |
| 2. | Reciprocal lattice, X-ray diffraction- Theory, Intensity calculation, Diffractometer, Crystal structure indexing, Phase analysis, Spectroscopic analysis, Defect analysis. | 16 |
| 3. | Texture analysis - Basics, Pole figure and orientation distribution function (ODF) analysis. | 08 |
| 4. | Transmission Electron Microscope – Equipment features, Sample preparation, Various targets, Electron optics, Imaging, double beam tilting, Kikuchi pattern analysis. | 10 |
| 5. | Selected area diffraction pattern (SADP) analysis, Electron dispersive spectroscopy, Electron energy loss spectroscopy, Convergent Beam Electron diffraction. | 06 |
| | Total | 44 |

**Suggested Reading:**

1. Elements of X-Ray Diffraction - B. D. Cullity and S. R. Stock
2. X-Ray and Electron Diffraction Studies in Materials Science - David Dyson
3. X-Ray Diffraction: A Practical Approach - C. Suryanarayana and M. Grant Norton
4. Electron Diffraction in the Transmission Electron Microscope - P. E. Champness

**MT 503: Metal Casting Technology** **3-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|

| | | |
|---|---|---|
| 1. | Casting as a manufacturing method. | 02 |
| 2. | Pattern making - design and selection of pattern materials. | 06 |
| 3. | Moulding; selection of moulding technique, mould-making materials - sand based aggregates, other materials for moulding, Sand testing, Various modern moulding and core-making techniques. | 08 |
| 4. | Melting: furnaces, melt treatment for ferrous and non-ferrous materials. Special casting methods - Die casting, Shell mould casting, EPC, Precision casting methods. | 08 |
| 5. | Outline of heat-treatment of selected alloy castings - important grades of alloy cast irons, Austempering of ductile iron; | 06 |
| 6. | Common grades of cast products, Rheo-casting and Thixocasting, Entrainment of films in molten metal. | 06 |
| 7. | Casting defects, remedies and quality assurance. | 06 |
| | Total | 42 |

**Suggested Reading:**

1. Casting Technology and Cast Alloys - A. K. Chakrabarti
2. Principles of Metal Casting - R. W. Heine, C. R. Loper and P. C. Rosenthal
3. Principles of Foundry Technology - P. L. Jain
4. Metal Casting: Computer-aided Design and Analysis - B. Ravi

**MT 504: Heat Treatment Technology** **2-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Review of physical metallurgy principles underlying heat treatment of steels, T-T-T and C-C-T diagrams, hardenability of steels, role of alloying elements in steels, annealing and normalizing heat treatments, quenching media and their characteristics, quenching and transformation stresses; Hardening and tempering of steels. | 14 |
| 2. | Surface hardening of steels: Chemical and non-chemical processes. | 04 |
| 3. | Thermal and thermo-mechanical treatment of metals and alloys; austempering, martempering, patenting, ausforming etc. | 06 |
| 4. | Heat treatment of plain carbon steels, tool and special alloy steels; Heat treatment of cast iron; Heat treatment of some important non-ferrous alloys. | 08 |
| 5. | Heat treatment defects and their rectifications. | 04 |
| 6. | Heat treatment furnaces and its atmosphere control. | 04 |
| 7. | Heat treatment shops: mechanization, automation and layout. | 02 |
| | Total | 42 |

**Suggested Reading:**

1. Heat Treatment: Principles and Techniques - T. V. Rajan, C. P. Sharma and Ashok Sharma

2. Steel and its Heat Treatment - K. E. Thelning
3. Steels: Heat Treatment and Processing Principles - G. Krauss
4. Heat Treater's Guide: Practices and Procedures for Irons and Steels - Harry Chandler
5. Heat Treater's Guide: Practices and Procedures for Nonferrous Alloys - Harry Chandler

**MT 505: Environmental Issues in Metallurgical Industries 3-0-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Concept of Environment: Classification of Pollutants and their sources. | 03 |
| 2. | Air pollution in industries. Control of specific air pollutants. | 05 |
| 3. | Characterization of waste waters: B.O.D., suspended solids, metals etc. Water quality standards and monitoring instruments. | 08 |
| 4. | Characterization of different industrial effluents, pollution control for specific pollutants, such as chromium, cadmium, mercury, phenolic wastes, arsenic, ammonia etc. | 10 |
| 5. | Pollution control: Iron & Steel industries - concept of zero $CO_2$ emission; Non-ferrous industries, plating and metal finishing industries. Disposal of solid wastes and their utilization. | 12 |
| 6. | Legislation and code of Practice with regard to pollution. | 04 |
| | Total | 42 |

**Suggested Reading:**

1. Energy and Environmental Management in Metallurgical Industries - R. C. Gupta
2. Handbook of Industrial Pollution and Control - S. C. Bhatia
3. Pollution Control in Chemical and Allied Industries - N. Hanley
4. Environment and Pollution: An Ecological Approach - R. S. Ambasht and P. K. Ambasht

**MT 551: Metal Casting Technology Lab 0-0-3 [F. M.: 100]**

| Sl. No. | Module Name and Topics | No. of Labs. |
|---|---|---|
| 1. | Demonstration of various types of patterns and core boxes: single piece, split and cope and drag | 01 |
| 2. | Study on Pattern drawing | 02 |
| 3. | Methoding of various gating systems on different types of patterns | 02 |

| | | |
|---|---|---|
| 4. | Wooden Pattern making | 02 |
| 5. | Orientation of the Foundry laboratory | 01 |
| 6. | Sand preparation (moulding and core sand) and testing of sand quality | 01 |
| 7. | Sand mould preparation - hand mould and machine mould | 02 |
| 8. | Core making : Oil core and $CO_2$ core | 01 |
| 9. | Metal casting (Aluminium) using sand mould and die casting moulds | 01 |
| 10. | Identification of casting defects and finding their possible solutions | 01 |
| | Total | 14 Labs. |

**MT 552: X-Ray and Electron Diffraction Lab 0-0-2 [F. M.: 50]**

| Sl. No. | Module Name and Topics | No. of Labs. |
|---|---|---|
| 1. | X-Ray diffractometer - demonstration of basic features and safety requirements | 01 |
| 2. | Operation and calibration of diffractometer | 01 |
| 3. | Recording X-Ray diffraction profile of standard samples (Si, $Al_2O_3$) - pattern analysis | 01 |
| 4. | Recording powder diffraction pattern of Al/Cu powders- pattern analysis | 01 |
| 5. | Microstructure and XRD pattern correlation and analysis of:<br>• as cast sample (Al/mild steel/Cu/Brass/Bronze) samples<br>• hot rolled sample (Al/mild steel/Cu/Brass/Bronze) samples<br>• cold rolled sample (Al/mild steel/Cu/Brass/Bronze) samples<br>• annealed sample (Al/mild steel/Cu/Brass/Bronze) samples<br>• cold rolled and annealed sample (Al/mild steel/Cu/Brass/Bronze) samples | 05 |
| 6. | Grain size determination by using Scherrer equation. Limitations and corrections | 01 |
| 7. | Residual stress in Al and Stainless steel samples –measurement and analysis | 02 |
| 8. | Crystal structure determination of unknown samples | 02 |
| | Total | 14 labs. |

**MT 553: Heat Treatment Technology Lab 0-0-3 [F. M. 100]**

| Sl No. | Module Name and Topics | Instruction | No. of Contact hours |
|---|---|---|---|
| 1. | Architecture of heat treatment furnaces | Common to all students. | 03 |
| 2. | Operation and maintenance of furnaces | | 03 |

| | | | |
|---|---|---|---|
| 3. | Thermocouple calibration | Carry out within the scheduled laboratory classes. | 03 |
| 4. | Determination of hardenability of steel (Jominy End Quench Test) | | 03 |
| 5. | Age hardening of AA6063 Al Alloy | Sl No. 5-15: Any two labs for a student as a project mode. | 30 (approx.) |
| 6. | Spheroidisation of SAE 52100 bearing steel | | |
| 7. | Precipitation hardening of Maraging steel | | |
| 8. | Secondary hardening of tool (AISI D2 or M2) steels | Students are allowed to choose material, define their objectives and concerned heat treatment schedules as well as post heat treatment characterizations. | |
| 9. | Duplex ageing behaviour of AA7075 Al alloy | | |
| 10. | Hardening and tempering of En24 steel | No fixed laboratory time. | |
| 11. | Cyclic heat treatment of high carbon steel | | |
| 12. | Thermo-Mechanical Processing of HSLA steel | Needs to submit electronic report within a specified time. | |
| 13. | Effects of cooling rate on microstructure and hardness of steel | | |
| 14. | Malleablisation of White Cast Iron | | |
| 15. | Heat treatment of Grey Cast Iron | | |
| | | Total | 42 hours |

**6th Semester:**

| Sl. No | Course Name | Course code | Class Load/Week | | | Credit | Class load/ week |
|---|---|---|---|---|---|---|---|
| | | | L | T | P | | |
| 1. | Polymer and Refractory Technology /Economics | CH601/HU5 601 | 2/2 | 1/1 | 0 | 3 | 3 |
| 2. | Mechanical Properties Evaluation | MT601 | 3 | 1 | 0 | 4 | 4 |
| 3. | Metallurgy of Ferrous Alloys | MT602 | 3 | 1 | 0 | 4 | 4 |
| 4. | Non-ferrous Materials | MT603 | 3 | 1 | 0 | 4 | 4 |
| 5. | EL I (DE):<br>Powder Metallurgy<br>Hydrometallurgy and Electrometallurgy | <br>MT604<br>MT605 | 3 | 0 | 0 | 3 | 3 |
| | Theory Sub-total | | 14/14 | 4/4 | 0 | 18 | 18 |
| | | | | | | | |
| 6. | Mechanical Properties Evaluation Lab | MT651 | 0 | 0 | 3 | 2 | 3 |
| 7. | Metallurgy of Ferrous Alloys Lab | MT652 | 0 | 0 | 3 | 2 | 3 |
| 8. | Communication Skill | MT653 | 0 | 0 | 2 | 1 | 2 |
| 9. | Comprehensive Viva-voce I | MT671 | 0 | 0 | 0 | 1 | 0 |
| | Sessional Sub-total | | 0 | 0 | 8 | 6 | 8 |
| | 6th Semester Total | | | | | 24 | 26 |

**After 6th semester, "industrial visit/3 to 4 weeks industrial training" is compulsory.**

**MT 601: Mechanical Properties Evaluation 3-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Introduction to mechanical behaviour of solids, Material properties and their classifications, Importance of evaluation of materials properties. | 04 |
| 2. | Hardness testing of metals. | 05 |
| 3. | Tensile testing of elastic, anelastic and plastic properties of materials. The relations between stress, strain, strain rate and temperature for plastically deformable solids. | 07 |
| 4. | Tests to evaluate compression, shear and impact properties of materials. Determination of the influence of composition, heat-treatment, microstructure, temperature, environmental effects etc. on mechanical properties of materials emphasizing the relationships between microstructure and mechanical properties. | 08 |
| 5. | Fatigue and creep in materials; tests to determine the fatigue and creep behaviours of materials. | 08 |
| 6. | Principles and techniques of non-destructive testing methods to evaluate materials characteristics - interpretation of test results. | 10 |
| | Total | 42 |

**Suggested Reading:**


1. The Testing and Inspection of Engineering Materials - H. E. Davis, G. E. Troxell and C. T. Wiskocil
2. Mechanical Metallurgy - G. E. Dieter
3. Testing of Metallic Materials – A. V. K. Suryanarayana
4. Practical Non-Destructive Testing - Baldev Raj, T. Jayakumar and M. Thavasimuthu


**MT 602: Metallurgy of Ferrous Alloys 3-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Properties of pure iron; effect of impurities on the characteristics of iron, Interstitial and substitutional solid solution of iron; Solubility and diffusivity of solute atoms in iron based systems. | 05 |
| 2. | Diffusional and non-diffusional phase transformation in steels - pearlitic, bainitic and martensitic transformations. Effect of alloying elements on the structure and properties of steel. | 05 |
| 3. | Theory of strengthening of steels. Controlled thermo-mechanical processing of steels. | 05 |
| 4. | Evolution of microstructures in low and high alloy steels, Effect of multiphase microstructure on the mechanical properties of steel. | 05 |

| | | |
|---|---|---|
| 5. | Physical metallurgy of new generation steels - ultra low carbon steels, precipitation hardenable steels, steels inheriting transformation induced plasticity, high strength low alloy steels, Ultrahigh strength steels. | 06 |
| 6. | Emerging steels for off shore and on shore applications. Theories for improvement of time dependent properties of steels. | 04 |
| 7. | Theories of nucleation and growth of graphite in grey and white cast iron. Alloying of cast iron - its influence on the microstructures, Effect of microstructures on the properties of alloy cast iron. Austempered ductile iron, its processing-structure-property correlation, emerging alloy cast iron of varying morphology of graphite. | 12 |
| | Total | 42 |

**Suggested Reading:**

1. Physical Metallurgy of Steels - W. C. Leslie
2. Physical Metallurgy and the Design of Steels - F. B. Pickering
3. Steels: Microstructure and Properties - H. K. D. H. Bhadeshia and R. W. K. Honeycombe
4. Cast iron Technology - Roy Elliott

**MT 603: Non-Ferrous Materials 3-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Basic steps in extraction of important non-ferrous metals with flow sheet; Roasting - Kellogg diagram, techniques of roasting. | 10 |
| 2. | Fundamental steps for extraction of Cu, Ni, Zn, Al, Mg, Ti and nuclear metals. | 10 |
| 3. | Principle of selection of extraction steps from specific types of ores; Waste treatment, waste management and Environmental aspects. Numerical problems related to extraction and refining including material balance. | 08 |
| 4. | Elements of physical metallurgy of non-ferrous metals - classification, physical, chemical and mechanical properties of some important aluminium, titanium, copper and other important non-ferrous alloys. | 10 |
| 5. | Heat treatment of some important non-ferrous alloys and their applications. | 04 |
| | Total | 42 |

**Suggested Reading:**

1. Extraction of Nonferrous Metals - H. S. Ray, R. Sridhar and K. P. Abraham
2. Modern Technology of Nonferrous Metals and Metal Extraction- EIRI Books
3. ASM Handbook: Vol. 2: Properties and Selection: Nonferrous Alloys and Special Purpose Materials
4. Structure-Property Relations in Nonferrous Metals - A. M. Russell and K. L. Lee

**MT 604: Powder Metallurgy** **2-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Development and scope of powder metallurgy; Different metal powder production methods viz., milling, atomization, reduction, electrolysis, carbonyl processes. | 10 |
| 2. | Characterization of metal powders - chemical composition, structure, shape, size and their determination; powder flow, apparent density, tap density, compressibility and porosity measurements; treatment of metal powders. | 10 |
| 3. | Behaviour of metal powders during compaction, Different compaction techniques like die compaction, isostatic pressing, powder rolling, powder extrusion etc. Types of presses, tooling and die design. | 10 |
| 4. | Mechanism of sintering of metal powders; solid state and liquid phase sintering; evaluation of sintered product. | 06 |
| 5. | Production and uses of powder metallurgy products viz. Filters Contact materials, Bearings, Structural parts and dispersion strengthened materials. | 06 |
| | Total | 42 |

**Suggested Reading:**


1. Powder Metallurgy: Its Physics and Production - Paul Schwarzkopf, Claus G. Goetzel and George Stern
2. Powder Metallurgy: Science, Technology and Materials - Anish Upadhyaya and G. S. Upadhyaya
3. ASM Handbook: Vol. 7: Powder Metallurgy
4. Powder Metallurgy - A. K. Sinha


**MT 605: Hydrometallurgy and Electometallurgy** **2-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Minerals and ores; pyro- and hydrometallurgy - selection of the extraction process route; steps involved in hydrometallurgy and electrometallurgy; importance of hydrometallurgy for utilizing lean grade ores and for extraction metals for nuclear applications. | 10 |
| 2. | Thermodynamics of solutions- ideal solutions: activity of elements in dilute solutions; review of laws of electrolysis – Debye and Huckels theory of electrolytic dissociation; Pourbaix (Predominance area diagram). | 08 |
| 3. | Leaching of ores - mechanisms, thermodynamics of reactions - Nernst equation and applications; selection of leachants; specific extraction processes of copper, nickel, zinc, gold etc; role of oxygen in leaching; kinetics of leaching- factors involved. | 10 |

| | | |
|---|---|---|
| 4. | Bacterial or microbial leaching - reaction mechanism of aerobic and anaerobic bacteria; factors involved in bacteria-assisted reactions, practical aspects. | 06 |
| 5. | Purification of leach liquor - Solvent Extraction and Ion Exchange; flow charts; Electrolytic recovery of metals from aqueous solutions and from melts; calculation of current and voltage efficiency of electrolytic processes. | 06 |
| 6. | Flow charts of extraction processes of copper, nickel, uranium, zinc etc. | 02 |
| | Total | 42 |

**Suggested Reading:**

1. Principles of Extractive Metallurgy - A. Ghosh and H. S. Ray
2. Hydrometallurgy - S. Venkatachalam
3. Hydrometallurgy - Fathi Habashi
4. Unit Processes of Extractive Metallurgy - R. D. Pehlke

**MT 651: Mechanical Properties Evaluation Lab 0–0–3 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Labs. |
|---|---|---|
| 1. | Introduction | 01 |
| 2. | Hardness Measurements: Rockwell, Brinell, Vickers, Poldi, Shore | 05 |
| 3. | Micro Hardness Testing: Vickers | 02 |
| 4. | Impact Testing: Charpy | 01 |
| 5. | Tensile Testing using Instron Machine with and without extensometer | 02 |
| 6. | Erichsen Cupping Test | 01 |
| 7. | Non Destructive Testing: Dye Penetrant and Magnetic Particle test | 02 |
| | Total | 14 Labs. |

**MT652: Metallurgy of Ferrous Alloys Lab 0-0-3 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Labs. |
|---|---|---|
| 1. | Study of microstructure of as-cast steel- Hadfield Manganese steel. | 01 |
| 2. | Microstructure evolution of (i) as cast, (ii) as rolled and (iii) various heat treated EN-8 steel specimens. | 02 |
| 3. | Microstructure evolution of (i) as cast, (ii) as rolled and (iii) various heat treated EN-31 steel specimens. | 02 |
| 4. | Microstructure evolution of 1.1% carbon steel in (i) fully annealed, (ii) spheroidised annealed, (iii) normalized, (iv) oil quenched and (v) quenched and tempered conditions. | 03 |

| | | |
|---|---|---|
| 5. | Evolution of microstructure and hardness evaluation of low carbon steel under continuous cooling conditions. | 01 |
| 6. | Microstructure evolution of high alloy steel (i) austenitic stainless steel, (ii) 2205 and 2507 grade duplex stainless steels and (iii) TWIP steels. | 03 |
| 7. | Microstructure evolution of various types of general purpose cast irons and alloy cast irons. | 02 |
| | Total | 14 Labs. |

**MT653: Communication Skill 0-0-2 [F.M.: 50]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Introduction to communication skills | 01 |
| 2. | Attainment descriptors for communication skills | 01 |
| 3. | Definition of listening, reading, writing and communicating | 01 |
| 4. | Barriers in the path of communication, signposting, outlines, rephrasing, listening to conversation (Formal and Informal) | 01 |
| 5. | Techniques of reading, skimming, scanning, SQ3R technique, writing skills, paragraph | 02 |
| 6. | Power point presentation of current topics | 08 |
| | Total | 14 |

**Suggesting Reading:**

1. How to Effectively Communicate - Paul Newton
2. Interpersonal Skills for Entrepreneurs - Melissa Contreras

**7th Semester:**

| Sl. No | Course Name | Course code | Class Load/Week | | | Credit | Class load/ week |
|---|---|---|---|---|---|---|---|
| | | | L | T | P | | |
| 1. | Joining of Materials | MT701 | 2 | 1 | 0 | 3 | 3 |
| 2. | Degradation of Materials & Their Prevention | MT702 | 2 | 1 | 0 | 3 | 3 |
| 3. | Composites and Ceramic Materials | MT703 | 2 | 1 | 0 | 3 | 3 |
| 4. | Accounts & Financial Mgmt | HU 7------ | 2 | 0 | 0 | 2 | 2 |
| 5. | EL II (OE):- | MT731/1 | 2/2 | 1/1 | 0 | 3/3 | 3/3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Theory Sub-total | | 10/10 | 4/4 | NIL | 14/14 | 14/14 |
| | | | | | | | |
| 6. | Joining of Materials Lab | MT751 | 0 | 0 | 3 | 2 | 3 |
| 7. | Degradation of Materials & Their Prevention Lab | MT752 | 0 | 0 | 3 | 2 | 3 |
| 8. | Composites and Ceramic Materials Lab | MT753 | 0 | 0 | 3 | 2 | 3 |
| 9. | Project & Thesis I | MT754 | 0 | 0 | 2 | 1 | 2 |
| | Sessional Sub-total : | | NIL | NIL | 11 | 7 | 11 |
| | 7th Semester Total | | | | | 21/21 | 25/25 |

EL II (OE):

(i) Selection of Engineering Materials MT731/1 (OE) - to be offered for other departments ( All ).

**MT 701: Joining of Materials** **2-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Basic Welding Processes, their principles and applications - Gas Welding, Arc Welding, Thermit Welding, Resistance Welding, Spot Welding, Pressure Welding etc. | 06 |
| 2. | Advanced Material Joining Techniques - TIG, MIG, Submerged Arc Welding, Electro-slag Welding, Plasma Arc. Welding, Electron Beam Welding, Laser Beam Welding, Ultrasonic Welding, Explosive Welding, Atomic Hydrogen Welding, Under Water Welding, Diffusion Bonding, Friction Stir Welding etc.<br>Principles of Brazing, Soldering and joining of dissimilar materials. | 10 |
| 3. | Selection of Joining Process; Classification of Electrodes & Weld Joints, Welding Codes, Weld ability of different Materials and their Metallurgical and Mechanical aspects. | 08 |
| 4. | Physics of Welding - Welding Arc and their types, structure, mechanism, stability and characteristics, Mechanism of Arc blow, its effect and remedies. Types of metal transfer and forces affecting it. | 10 |

| | | |
|---|---|---|
| 5. | Defects: Residual stresses and distortion in welded joints and their remedies. Design, Inspection & Testing of weld joints, Economics of joining processes. | 06 |
| | Total | 40 |

**MT702: Degradation of Materials & Their Prevention 2-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Introduction: Technical and economic aspect of the study of corrosion; review of the electrochemical principles of corrosion cell; exchange current density; electrode potential and standard cells, EMF series and galvanic series— their applications; Polarization: types, factors involved, effect on corrosion rate; application of Faraday's law in corrosion. | 10 |
| 2. | Mixed Potential theory; Tafel equation, construction and interpretation of Polarization diagrams, different forms of corrosion-uniform attack, galvanic, crevice, pitting, intergranular, selective leaching, erosion corrosion and stress corrosion cracking, Hydrogen effect, corrosion fatigue and liquid metal embrittlement-their characteristic features, causes and remedial measures; corrosion testing methods and interpretation of results. | 16 |
| 3. | Oxidation — Oxide films, Pilling-Bedworth ratio, and their effects on kinetics, oxide defect structures, rate laws, types of oxidation, materials for use at elevated temperatures. | 6 |
| 4. | Principles of corrosion prevention-material selection and design aspects; control of environment including inhibitors, cathodic and anodic protection, coatings and other surface protection techniques of metals and alloys. | 6 |
| 5. | Degradation by wear of materials; its characteristics, wear testing, Wear-resistant materials. | 4 |
| | Total | 42 |

**MT 703: Composites and Ceramic Materials 2-1-0 [F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Composite Materials: Classification of composite materials. Dispersion strengthened, particle reinforced and fiber reinforced composites, Mechanics and strengthening | 6 |

| | | |
|---|---|---|
| | mechanisms in composite materials. Properties of composites: Elastic Properties, Strength and toughness. | |
| 2. | Design of composites; In-situ and ex-situ composites; Interfaces between reinforcements and matrices in composites; Bonding Mechanisms, Bond Strength, Interfacial Toughness. | 6 |
| 3. | Polymer Matrix Composites: Polymer Matrices, Processing Techniques, Glass Reinforced Plastics, Carbon Fiber Composites; Metal matrix Composites; Metal Matrices, Processing Techniques, Interfacial Controls, Discontinuously Reinforced Composites, Fiber Composites; Ceramic Matrix Composites: Ceramic Matrices, Processing Techniques, Alumina Matrix Composites, Glass Matrix Composites, Nanocomposites and its usefulness. | 8 |
| 4. | Ceramic Materials: Introduction to ceramics as engineering materials, Common crystal structures in ceramics; Silicates, clay, minerals, graphite and carbides, structure of glasses. Imperfections in ceramics, Classification of ceramics and their applications; Ceramic raw materials and their characterization, Raw material preparation and processing of ceramics, Casting processes like drain casting, tape casting etc. Properties of ceramic powder particle-size, shape and surface properties. Flocculation and rheology. | 8 |
| 5. | Phase diagrams and phase transformation in ceramic material. Forming Processes: Extrusion, Pressing, Injection Moulding. | 4 |
| 6. | Mechanical behavior of structural ceramics-brittleness and its improvement, Different toughness measuring techniques. Significance of Fracture toughness, elastic modulus and strength of structural ceramics.<br>Electrical, magnetic and optical properties of important ceramic systems. | 6 |
| 7. | Functional ceramics diverse application in cutting tool, mobile phone microwave devices polycrystalline diamond and solid oxides for fuel cells, Introduction to electro active ceramics and bio-ceramics. | 6 |
| | Total | 44 |

**MT731/1: Selection of Engineering Materials (OE II) 2-1-0[F.M.:100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Relationship between processing— structure-properties of various engineering materials, Materials selection criteria-shape, micro structural factors, performance criteria in service and other strategic requirements of engineering components to be designed. Economic considerations. | 14 |
| 2. | Technologically important material properties-physical, mechanical, chemical, thermal optical and electrical properties, Materials used in important engineering sectors. | 12 |

| | | |
|---|---|---|
| 3. | Types of design, materials data and design tools, Methodology for selection of materials for the components, selection of processes to meet the design requirements, Systematic selection process-pertinent case studies, Multiple constraints; its handling strategies. | 14 |
| | Total | 40 |

**MT 751: Joining of Materials Lab 0-0-3 [F. M.: 100]**

| Sl. No. | Module Name and Topics | No. of Contact hours |
|---|---|---|
| 1. | Visit to the lab and acquaintance with the equipment | 3 |
| 2. | Soldering & brazing with on hand practice | 6 |
| 3. | Gas cutting and welding | 6 |
| 4. | Resistance spot welding | 3 |
| 5. | Manual Metal Arc Welding (MMAW) with on hand practice and spatter loss calculation | 6 |
| 6. | TIG and MIG welding with on hand practice | 9 |
| 7. | Submerged Arc Welding | 3 |
| 8. | Plasma arc cutting for stainless steel and non-ferrous metals and alloys | 3 |
| 9. | Repeat process | 3 |
| 10. | Laboratory Viva-voce | 3 |
| | Total | 45 hours |

**MT 752: Degradation of Materials & Their Prevention Lab 0-0-3 [F. M.: 100]**

| Sl. No. | Module Name and Topics | No. of contact hours |
|---|---|---|

| | | |
|---|---|---|
| 1. | Visit to the lab and acquaintance with the equipment | 3 |
| 2. | Immersion test in various solutions with analysis | 12 |
| 3. | Potentiodynamic polarisation studies in various electrolytes with analysis | 9 |
| 4. | Electrochemical Impedance Spectroscopy with analysis | 6 |
| 5. | Examination, analysis and interpretation of corroded surfaces and products | 6 |
| 6. | Repeat process | 3 |
| 7. | Laboratory Viva-voce | 3 |
| | Total | 42 hours |

**MT 753: Composites and Ceramic Materials Lab 0-0-3[F. M.: 100]**

| Sl. No. | Module Name and Topics | No. of contact hours |
|---|---|---|
| 1. | Visit to the lab and acquaintance with the equipment | 3 |
| 2. | Preparation of metal matrix composite | 3 |
| 3. | Metallographic and mechanical properties study of different composite materials | 18 |
| 4. | Metallographic and mechanical properties study of different ceramic materials | 12 |
| 5. | Repeat process | 3 |
| 6. | Laboratory Viva-voce | 3 |
| | Total | 40 |

**MT754: Project Thesis I 0-0-2 [F.M.:50]**

| Sl. No. | Module Name and Topics | No. of contact hours |
|---|---|---|
| 1. | Selection of topic, literature review, work plan, report submission and its presentation by each student, question-answer session by the fellow students and faculty members. | 26-30 hours |

| | | |
|---|---|---|
| | Total | 26-30 hours |

**8th Semester:**

| Sl. No | Course Name | Course code | Class Load/Week | | | Credit | Class load/ week |
|---|---|---|---|---|---|---|---|
| | | | L | T | P | | |
| 1. | Materials Processing | MT801 | 3 | 1 | 0 | 4 | 4 |
| 2. | Materials Characterisation | MT802 | 2 | 1 | 0 | 3 | 3 |
| 3. | Design and Selection of Materials | MT803 | 2 | 1 | 0 | 3 | 3 |
| | | | | | | | |
| 4. | Elective II (DE):- | MT821/1<br>MT821/2 | 3 | 0 | 0 | 3 | 3 |
| 5. | Elective III (DE):- | MT822/1<br>MT822/2 | 2 | 1 | 0 | 3 | 3 |
| | Theory Sub-total | | 12 | 4 | 0 | 16 | 16 |
| | | | | | | | |
| 6. | Materials Processing Lab | MT851 | 0 | 0 | 3 | 2 | 3 |
| 7. | Materials Characterisation Lab | MT852 | 0 | 0 | 3 | 2 | 3 |
| 8. | Project Thesis II | MT853 | 0 | 0 | 4 | 2 | 4 |
| 9. | Project Thesis II Viva-voce | MT854 | 0 | 0 | 0 | 1 | 0 |
| 10. | Comprehensive Viva-Voce II | MT871 | 0 | 0 | 0 | 2 | 0 |
| | Sessional Sub-total | | NIL | NIL | 10 | 9 | 10 |
| | 8th Semester Total | | | | | 25 | 26 |

1) Elective II (DE):-

(i) Nano-structured and functionally graded materials ( MT821/1 )

(ii) Principles of Thin Films and Coatings ( MT821/2 )

2) Elective III (DE):-

i) Fracture Mechanics and Failure Analysis ( MT822/1 )

ii) Transportation Phenomena in Metallurgical Industries ( MT822/2 )

**MT 801: Materials Processing 3-1-0[F.M.:100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Fundamental of metal working: Classification of forming processes, mechanics of metal working, temperature in metal working - hot working vs. cold working, strain rate effects, sliding and sticking friction, lubrication, residual stress. | 8 |
| 2. | Forging: general aspects, closed-die and open-die forging, different types of forging equipment; forging in plane strain, forging loads, forging defects. | 6 |
| 3. | Rolling: terminology of rolled products, different types of rolling mills; deformation zone, neutral point, angle of bite, draft in rolling; forward slip and backward slip, derivation of rolling load, friction hill, roll flattening, rolling variables; problem and defects in rolled products. | 10 |
| 4. | Extrusion: direct and indirect extrusion, hydrostatic extrusion, extrusion equipment, derivation of extrusion pressure, deformation, lubrication and defects in extrusion. | 6 |
| 5. | Drawing: process and equipments, hydrodynamic lubrication, maximum possible reduction in a pass under ideal condition, draw stress with friction and back tension; common defects, production of tubes including seamless tubes by extrusion and rolling. | 6 |
| 6 | Sheet metal forming: different forming methods, forming limit criteria, defects in formed parts; Automation and recent advances in metal working technology. | 6 |
| | Total | 42 |

**MT802: Materials Characterisation 2-1-0 [F.M.:100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Fundamentals of crystallography, reciprocal lattice and structure analysis in materials. Determination of grain size and lattice strain from X-ray diffraction patterns. | 6 |
| 2. | Fundamentals of electron microscopy - possible interactions between specimen and the incident electron beam. Construction and application of transmission and scanning | 16 |

| | | |
|---|---|---|
| | electron microscopes in materials characterization. Electron probe micro analyzer; Principles and application of Auger electron spectroscopy, Scanning tunneling microscopy; Atomic force microscopy. | |
| 3. | Thermal analyses as tools for materials characterization. Dilatometry, resistivity and magnetic measurements in materials characterization. | 8 |
| 4. | Advances in characterization techniques. | 10 |
| | Total | 40 |

**MT 803: Design and Selection of Materials 2-1-0 [F. M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Relationship between processing-structure-properties of various engineering materials, Materials selection criteria-shape, micro structural factors, performance criteria in service and other strategic requirements of engineering components to be designed. Economic considerations. | 14 |
| 2. | Technologically important material properties: physical, mechanical, chemical, thermal optical and electrical properties, Materials used in important engineering sectors. | 12 |
| 3. | Types of design, materials data and design tools, Methodology for selection of materials for the components, selection of processes to meet the design requirements, Systematic selection process-pertinent case studies, Multiple constraints; its handling strategies. | 14 |
| | Total | 40 |

**MT 821/1 (DE II): Nano-structured and functionally graded materials 3-0-0 [F. M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Introduction to Nanoscience and Nanotechnology. Underlying physical principles of nanotechnology: Nanostructured Materials, Fundamental physicochemical principles underlying the size dependence of the properties of nanostructured matter. | 10 |

| | | |
|---|---|---|
| 2. | Quantum confinement, single electron charging, Synthesis of nanostructured materials. Top down and bottom up approaches to building nanostructured materials. Properties of nanomaterials. Overview of self-assembly. | 12 |
| 3. | The basic tools of nanotechnology, scanning probe microscopy and near-field optics; electron and ion-based microscopy and manipulation. | 8 |
| 4. | Introduction to functionally graded materials, classification of functionally graded materials, properties and preparation techniques. Areas of application. | 10 |
| | Total | 40 |

**MT 821/2 (DE II): Principles of Thin Films and Coatings 3-0-0**
**[F.M.:100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Introduction to thin films, Environment and molecular and plasma processes in thin film deposition; Cold and thermal plasma; Requirement for substrate: Substrate cleaning; Formation of thin films Sticking coefficient, Formation of thermodynamically stable cluster – nucleation and Growth process; Properties of thin films: Microstructure. Single crystalline films. Polycrystalline films. | 10 |
| 2. | Nanocrystalline thin film. Amorphous films, Metastable films, Surface morphology, Film density, Stress in thin films, Adhesion. Stoichiometry. | 8 |
| 3. | Mechanical, electrical, thermal, chemical, and optical properties of thin films. | 4 |
| 4. | Thermal evaporation Resistance evaporation. Electron beam evaporation. Molecular beam epitaxy; Laser ablation. Synthesis of nanomaterials (nanowires, nanoribbons); Electrical discharges used in thin film deposition Mechanism of electrical discharges. I-V characteristic of electrical discharges. Townsend discharge. Glow discharge Arc. | 10 |
| 5. | Practical electric discharge configuration for deposition of thin films, Direct current electric discharges. Radio-frequency discharges, Microwave discharges, Electron cyclotron resonance plasma, Matching units, Floating potential, Bias potential, Plasma potential, Effective bias, Self-bias. | 8 |
| | Total | 40 |

**MT 822/1 (DE III): Fracture Mechanics and Failure Analysis 2-1-0[F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Introduction; Continuum Mechanics: stress, strain; Linear Elasticity; beam theory, constitutive laws; | 4 |
| 2. | Linear Elastic Fracture Mechanics: K1 singularity, plasticity considerations, KIC, CTOD, resistance curves, plane-stress analyses; | 6 |
| 3. | Interfacial Fracture Mechanics: theory, crack-path considerations; sub critical crack growth; Plasticity; yield criteria, deformation and flow theories, constitutive laws, Prandtl-Reuss equations, limit analysis. | 8 |
| 4. | Nonlinear Elastic Fracture Mechanics: HRR singularity, JIC, JR ($\Delta a$) resistance curves, TR, CTOA, non-stationary crack-growth analysis. | 8 |
| 5. | Environmentally-Assisted Fracture; stress corrosion, hydrogen embrittlement, corrosion fatigue, Cyclic Fatigue Failure: mechanistic aspects, crack propagation, damage-tolerant analysis, variable amplitude loading small cracks, crack closure, stress-strain/ life analysis. | 10 |
| 6. | Physical Basis of Toughness: intrinsic toughening - metals, extrinsic toughening - ceramics, composites, Fracture statistics. | 6 |
| | Total | 42 |

**MT 822/2 (DE III): Transportation Phenomena in Metallurgical Industries 2-1-0[F.M.:100]**

| Sl. No. | Module Name and Topics | No. of Lectures |
|---|---|---|
| 1. | Review of the basic concepts in heat, mass and momentum transfer. | 6 |
| 2. | Empirical treatment of reaction rates, activated state. | 6 |
| 3. | Various expressions for reaction velocity and rate equations, rate controlling mechanisms: Reduced time plots. | 9 |

| | | |
|---|---|---|
| 4. | Phenomena in heterogeneous kinetics of transformation of single particles and particulate beds by fluids. | 12 |
| 5. | Some kinetic models. Selected examples from metallurgical engineering. | 9 |
| | Total | 42 |

**MT851: Materials Processing Lab 0-0-3[F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of contact hours |
|---|---|---|
| 1. | Visit to the lab and acquaintance with the equipment | 3 |
| 2. | Characterisation of powder using optical microscope (OM) | 6 |
| 3. | Green compaction of powder using hydraulic press | 3 |
| 4. | Measurement of green density | 3 |
| 5. | Sintering of green compacted powder sample | 6 |
| 6. | Hardness measurement and microstructural study of sintered samples | 6 |
| 7. | Hot forging and cold and hot rolling practices | 6 |
| 8. | Repeat process | 3 |
| 9. | Laboratory Viva-voce | 3 |
| | Total | 39 hours |

**MT852: Materials Characterisation Lab 0-0-3[F.M.: 100]**

| Sl. No. | Module Name and Topics | No. of contact hours |
|---|---|---|
| 1. | Visit to the lab and acquaintance with the equipment | 3 |
| 2. | Determination of grain size using Scherrer formula in X-ray diffraction | 6 |

| | | |
|---|---|---|
| 3. | Measurement of lattice strain using single line profile (SLP) analysis | 6 |
| 4. | Study of surface topography and determination of chemical composition of precipitate particles using SEM and EDS facilities. | 6 |
| 5. | Study of thin foil and powder sample using TEM | 6 |
| 6. | Study of phase transformation using DSC | 6 |
| 7. | Repeat process | 3 |
| 8. | Laboratory Viva-voce | 3 |
| | Total | 39 hours |

**MT853: Project Thesis II** **0-0-4**
**[F.M.:100]**

| Sl. No. | Module Name and Topics | No. of contact hours |
|---|---|---|
| 1. | Literature review on selected topic, work done, report submission and its presentation by each student, question-answer session by the fellow students and faculty members. | 52-60 hours |
| | Total | 52-60 hours |

**MT854: Project & Thesis II Viva-Voce** **0-0-0[F.M.:50]**

| Sl. No. | Module Name and Topics | No. of contact hours |
|---|---|---|
| 1. | Viva-voce examination pertaining to project work done | 0 |
| | Total | 0 |

**MT871: Comprehensive Viva-Voce II** **0-0-0[F.M.:100]**

| Sl. No. | Module Name and Topics | No. of contact hours |
|---|---|---|
| 1. | Viva-voce examination pertaining to theory subjects of 7th and 8th semesters | 0 |
| | Total | 0 |