B. Tech. Curriculum for Metallurgical and Materials Engineering

SEMESTER-III

Name of the Subject	Type	Subject Code	L-T-P	Credit	Contact Hour
	HSS 2			3	3
Metallurgical Thermodynamics	DC 1	MM2L001	3-0-0	3	3
Transport Phenomena	DC 2	MM2L002	3-0-0	3	3
Structure of Materials	DC 3	MM2L003	3-0-0	3	3
Metal Processing	SDC 3	MM2L004	3-0-0	3	3
Thermodynamics and Kinetics of Materials Laboratory	Lab-4 (DC 1)	MM2P001	0-0-3	2	3
Metal Processing Laboratory	Lab-5 (DC 2)	MM2P002	0-0-3	2	3
Total				19	21

SEMESTER-IV

Name of the Subject	Type	Subject Code	L-T-P	Credit	Contact Hour
	HSS 3			3	3
Physical Metallurgy	DC 4	MM2L005	3-0-0	3	3
Computational Materials Engineering	DC 5	MM2L006	3-0-2	4	5
Nonferrous Extractive Metallurgy	DC 6	MM2L007	3-0-0	3	3
Mineral Processing	SDC 4	MM2L008	2-0-2	3	4
Process Control and Instrumentation Laboratory	Lab-6 (DC 3)	MM2P003	0-0-3	2	3
Physical Metallurgy Laboratory	Lab-7 (DC 4)	MM2P004	0-0-3	2	3
OE	OE 1			3	3
Total				23	27

Syllabus for 2nd Year (3rd & 4th Semesters)

Subject Code: MM2L001	Name: Metallurgical Thermodynamics	L-T-P-C: 3-0-0-3
Prerequisite: None		

Module 1: (Basic Concepts) (8 hours)
System, surroundings, state functions, thermodynamic equilibrium, zeroth law of thermodynamics, first law of thermodynamics and applications to closed systems, second law of thermodynamics, entropy, and criteria for spontaneity, third law of thermodynamics.

Module 2: (Fundamental Equations and Their Relationships) (8 hours)
Heat capacity, enthalpy, Hess's law, Helmholtz and Gibbs free energy, Maxwell relations and their applications, statistical thermodynamics, chemical potential and partial molar properties.

Module 3: (Phase Equilibria) (10 hours)
Gibbs free energy and equilibrium criteria, Gibbs phase rule, phase equilibria in single and multicomponent systems, phase diagrams: unary, binary (isomorphous, eutectic, peritectic systems), Clausius–Clapeyron equation and its applications.

Module 4: (Solutions and Reactions) (12 hours)
Behavior of gases, behavior of solutions, ideal and non-ideal solutions, activity, activity coefficients, and Raoult's & Henry's laws, thermodynamics of real solutions (regular and sub-regular solutions), reaction thermodynamics, Ellingham diagrams and their applications in metallurgical processes.

Module 5: (Electrochemistry) (10 hours)
Types of cells, electromotive force, Nernst equation, electrochemical series, Pourbaix diagrams, Predominance diagrams.

Text Books:

1. D. R. Gaskell & D. E. Laughlin, "Introduction to the Thermodynamics of Materials", CRC Press, Boca Raton, Seventh edition, 2025.
2. R. DeHoff, "Thermodynamics in Materials Science", CRC Press, Boca Raton, Second edition, 2006.
3. H. G. Lee, "Chemical Thermodynamics for Metals and Materials", Imperial College Press, London, 1999.

Reference Books:

1. R. A. Swalin, "Thermodynamics of Solids", John Wiley and Sons, New York, Second edition, 1972.
2. G. S. Upadhyaya & R. K. Dube, "Problems in Metallurgical Thermodynamics and Kinetics", Pergamon Press, Oxford, First edition, 1977.

Subject Code: MM2L002	Name: Transport Phenomena and Kinetics of Metallurgical Processes	L-T-P-C: 3-0-0-3
Prerequisite: None		

Module 1: Overview and Fundamentals (2 hours)

Kinetics and transport phenomena in materials processing; continuum hypothesis and limitations; scalar and tensor quantities; pressure and stress tensor; control mass and control volume.

Module 2: Analogy Between Transport Processes (1 hour)

Fourier's law, Fick's law, Newton's law of viscosity; mathematical analogy among transport phenomena; common boundary conditions.

Module 3: Conservation Principles and Transport Equations (10 hours)

Shell balances; conservation of mass, momentum and energy; integral and differential forms; Reynolds Transport Theorem; steady and transient applications.

Module 4: Scaling and Dimensionless Analysis (1 hour)

Buckingham π theorem; dimensionless numbers; similarity and scale-up.

Module 5: Flow Phenomena in Materials Processing (6 hours)

Laminar and turbulent flow; velocity profiles; boundary layers; friction factor; flow around spheres; packed beds; Ergun equation; fluidization and elutriation; Bernoulli equation.

Module 6: Heat Transfer (7 hours)

Conduction, convection and radiation; transport-reaction coupling; heat transfer correlations.

Module 7: Mass Transfer (5 hours)

Film and penetration theories; mass transfer coefficients; diffusion in binary mixtures; Stefan problem; liquid-liquid and liquid-solid systems.

Module 8: Reaction Kinetics and Reactor Analysis (7 hours)

Law of mass action; homogeneous and heterogeneous reactions; fluid-solid and liquid-liquid reaction models; batch, CSTR and PFR; RTD; dispersion and tanks-in-series models; metallurgical case studies.

Text Books

1. Geiger, G.H. and Poirier, D.R., Transport Phenomena in Metallurgy, Addison-Wesley, 1973.
2. Bird, Stewart and Lightfoot, Transport Phenomena, 2nd Ed., Wiley, 2002.
3. Gaskell, Introduction to the Thermodynamics of Materials, CRC Press, 2008.
4. Sohn (Ed.), Reaction Kinetics in Metallurgical Systems, TMS, 2004.
5. Levenspiel, Chemical Reaction Engineering, 3rd Ed., Wiley, 1999.

Reference Books

6. Incropera et al., Fundamentals of Heat and Mass Transfer.
7. Welty et al., Fundamentals of Momentum, Heat and Mass Transfer.
8. Fogler, Elements of Chemical Reaction Engineering.

Subject Code: MM2L003	Name: Structure of Materials	L-T-P-C: 3-0-0-3

Prerequisite: None

Module 1: (Chemical bonding) (3 hours)
Arrangement of atoms in solids: Crystalline and noncrystalline states; Atomic bonding in solids; Introduction and historical development of crystallography.

Module 2: (Crystallography) (12 hours)
Periodic two- and three-dimensional network of points; Concept of Bravais lattice, Unit cells: Primitive and non-primitive, and types of Bravais lattices. Symmetry in lattice: translation and point symmetries, symmetry elements and operations, point and space groups; Symmetry analysis and classification of Bravais lattices.

Module 3: (Structure of crystals) (18 hours)
Crystal: Definition of basis; Symmetry analysis of crystal; Crystal structure of engineering materials (metals, alloys, and ceramics): Atomic positions: Lattice and interstitial sites, Atomic packing in crystal and close-packed structures, Pauling's structure rules for ionic solids; Crystallographic planes and directions: Miller and Miller-Bravais indices, Angular relationships among planes and directions; Stereographic projection. Reciprocal lattice: definition and properties; Relationship with real lattice, Ewald sphere construction.

Module 4: (Amorphous Materials) (02 hours)
Amorphous materials: factors controlling their structure, description of the structure of amorphous materials.

Module 5: (Defect structure) (7 hours)
Defects and disorder in materials: point defects: neutral and charged vacancies, interstitial and substitutional atoms/ions, Kroger-Vink notation, Line defects: Screw and edge dislocations; Grain and twin boundaries; Single- and polycrystalline- materials. Microstructures: Structural hierarchies: Nano-, micro-, meso-, macro-structures, Fundamentals of stereology and application to microstructural analysis

Text Books:

1. Balasubramaniam R, Callister's Materials Science and Engineering, Wiley, (2nd Ed.), 2014
2. Singh Vijendra, Physical Metallurgy, Standard Publishers Distributors, 2020
3. Verma A R, Srivastava O N, Crystallography Applied to Solid State Physics, New Age International Private Limited, (2nd ed.) 2020

Reference Books:

4. Structure of Materials by Marc De Graef and Michael E. McHenry (Cambridge University Press)

Subject Code: MM2L004	Name: Metal Processing	L-T-P-C: 3-0-0-3

Prerequisite: None

Module 1: Metal Casting (22 hours)

Basics of phase diagrams, Theory and modes of solidification (planar, cellular and dendritic), Constitutional supercooling, microstructure development; Basics of metal casting: Moulding sand mixture, mould and core making, running and feeding, common rules for casting design, melting furnaces and refractories; Different Casting techniques: temporary mould casting (sand casting, investment casting), permanent mould casting (gravity die casting, high pressure diecasting, centrifugal casting), Casting defects: Defects and testing (including Non Destructive Testing); Sustainable metal processing

Module 2: Powder metallurgy (6 hours)

Basics of processing of metal powders, Powder consolidation techniques; Advanced processing techniques like Metal additive manufacturing

Module 3: Welding (6 hours)

Fundamentals of welding, Welding techniques (TIG, MIG etc.), Welding of different metals and alloys, Weld defects and weld properties

Module 4: Heat Treatment (8 hours)

Basics of heat treatment processes in ferrous and non-ferrous systems

Text Books:

1. Zainul Huda, Springer Nature, Metal Casting Engineering: Design, Processes, Calculations, 2025
2. Randall M. German, Powder Metallurgy & Particulate Materials Processing, Metal Powder Industry, 2005
3. Sindo Kou, Welding Metallurgy, Wiley-Interscience, 2003
4. George Krauss, Steels: Heat Treatment and Processing Principles, ASM International, 2015

Reference Books:

1. Relevant ASM Handbooks

Subject Code: MM2P001	Name: Thermodynamics and Kinetics of Materials Laboratory	L-T-P-C: 0-0-3-2
Prerequisite: None		

List of Experiments:

1. Determination of heat capacity of materials (DSC-TGA-based method)
2. Determination of enthalpy change of a reaction
3. Determination of equilibrium constant as a function of temperature (Calcination of materials)
4. Verification of Clausius–Clapeyron relation (vapour pressure measurements)
5. Determination of diffusion coefficient in solids/liquids
6. Study of reduction kinetics of metals at elevated temperatures (Iron ore reduction experiments)
7. Determination of Fluidization velocity of particles (Iron ore and sands)
8. Determination of activation energy using Arrhenius plot (Roasting of Sulphides)
9. Determination of thermal conductivity of different powder materials
10. Computational thermodynamics: Introduction to phase diagram calculation (e.g., ThermoCalc/FactSage/Matlab-based tools)
11. Study of phase transformation using cooling curves (e.g., eutectic system)
12. To measure the viscosity of fluids

Reference Books:

1. D.R. Gaskell and D.E. Laughlin, Introduction to the Thermodynamics of Materials, CRC Press, 6th edition, 2017.
2. Robert W. Balluffi, Samuel M. Allen, and W. Craig Carter, Kinetics of Materials, John Wiley & Sons, 1st edition, 2005.
3. H. Scott Fogler, Elements of Chemical Reaction Engineering, Pearson Education, 5th edition, 2016.

Subject Code: MM2P002	Name: Metal Processing Laboratory	L-T-P-C: 0-0-3-2
Prerequisite: None		

1. To estimate particle size and grain fineness number by sieve analysis
2. To estimate the moisture and clay content in the green sand
3. To prepare standard sand samples and to estimate their strength
4. To estimate the permeability and shatter index of standard samples
5. To study the effect of cooling rate on microstructure in casting process
6. To measure flow rate, apparent and tap density of metal powders
7. To prepare green pellets and evaluate the effect of compaction pressure
8. To prepare sintered pellets and evaluate the effect of sintering temperature
9. To prepare alloys by mechanical alloying and arc melting, and evaluate the properties
10. To study the effect of TIG and MIG welding processes on microstructure and hardness
11. To study the effect of heat treatment (annealing, normalizing and quenching) on microstructure of steels

Subject Code: MM2L005	Name: Physical Metallurgy	L-T-P-C: 3-0-0-3
Prerequisite: Thermodynamics of Materials		

Module 1: Review of crystal structures and related topics (6 hours)
Lattice points, Motif, Unit Cells, Crystal structure, Crystal systems, Miller planes and directions, linear and planar atomic densities and their relation to slip

Module 2: Plastic deformation (8 hours)
Plastic deformation: Schmid law, Theoretical shear strength, Dislocations, Slip, Twinning
Module 3: Strengthening mechanisms (4 hours)
Grain size effects, Cold working, precipitation strengthening, martensitic transformation

Module 4: Nucleation (4 hours)

Homogeneous and Heterogeneous Nucleation

Module 5: Diffusion (6 hours)
Vacancies, Ficks first and second law, applications to carburization
Module 6: Heat treatment (8 hours)
Recovery, recrystallization and grain growth, TTT diagrams
Module 7: Phase diagrams (6 hours)
Phase rule, Binary phase diagrams, Invariant points, Lever rule, Fe-C phase diagram

Text Books:

1. R. Abbaschian, L. Abbaschian, R. E. Reed-Hill, Physical metallurgy principles, 4th edition, Cengage learning, 2013

Reference Books:

1. S. Avner, Introduction to physical metallurgy, 2nd edition, Mcgraw-Hill, 2017

Subject Code: MM2L006	Name: Nonferrous Extractive Metallurgy	L-T-P-C: 3-0-0-3

Prerequisite: None

- Introduction to non-ferrous metals: classification, importance, and applications; comparison with ferrous metallurgy. Overview of mineral resources and beneficiation of non-ferrous ores.
- Pyrometallurgical extraction: principles and processes involved in the extraction of Al, Ti, Cu, Zn, Mg, and Ni; roasting, smelting, converting, and refining.
- Hydrometallurgy: leaching techniques (acidic, alkaline, bioleaching), solvent extraction, ion exchange, precipitation methods; applications in Cu, U, and Au extraction.
- Electrometallurgy: principles of electrolysis, electro-winning, electro-refining; Hall-Héroult process for aluminum; electrochemical aspects of metal extraction.
- Extraction and refining of important non-ferrous metals: Copper: matte smelting, converting, fire refining, electrorefining Aluminum: Bayer process, Hall-Héroult process, Titanium: Kroll process. Lead and Zinc: sintering, blast furnace, Imperial Smelting Process, Calcium Magnesium: extraction routes and refining
- Secondary metallurgy and recycling of non-ferrous metals: sustainability and circular economy. Environmental aspects: pollution control, waste management, and energy considerations in non-ferrous metallurgy.
- Advances in non-ferrous metallurgy: green processes, low-carbon extraction, and emerging technologies.

Text Books:

4. Ray H.S., Sridhar R., Abraham K.P., Extraction of Nonferrous Metals, Affiliated East-West Press, 2007
5. Ray H.S., Principles of Extractive Metallurgy, New Age International 2004

Reference Books:

1. Rosenqvist T., Principles of Extractive Metallurgy, McGraw-Hill 2003
2. Gupta C.K., Chemical Metallurgy: Principles and Practice, Wiley-VCH 1980
3. Habashi F., Principles of Extractive Metallurgy, Gordon & Breach 2011

Subject Code: MM2L007	Name: Mineral Processing	L-T-P-C: 2-0-2-3

Prerequisite: None

Module 1: (Particle Population) (6 hours)
Introduction, Particle Size Distribution and Population Concepts; Characterization of particulate materials; Metallurgical accounting and sampling

Module 2: (Commination and Classification) (7 hours)
Feed preparation and comminution operations, including crushing, grinding, screening, Overview of energy–size relationships; Classification: fluid-particle interaction to describe classification processes, Hydrocyclone and heavy media separator,

Module 3: (Separation Techniques) (10 hours)
Major mineral separation techniques—such as gravity concentration, magnetic and electrical separation, and froth flotation. Emphasis on principles, equipment design, and typical applications; Solid-liquid separation processes such as thickening and filtration.

Module 4: (Hydrometallurgical Processes) (5 hours)
An introductory understanding of hydrometallurgical methods, including leaching, ion exchange, and solvent extraction.

Laboratory Practice (15 hours)

1. Batch grinding in laboratory ball mill (Experiment)
2. Ore Crushing in jaw and roll crushers (Demo and report writing)
3. Particle classification in hydrocyclone test rig (Experiment)
4. Particle size characterization by sieve analysis and Andreason pipette (Experiment)
5. Gravity separation in mineral jig separator and wet shaking table concentrator (Demo and report writing)
6. Froth flotation in a laboratory semi-batch flotation cell (Experiment)
7. Estimation of thickener diameter by Kynch test (Calculations from available Data)

Text Books:

1. Mineral Processing Technology, B.A. Wills, T.J. Napier-Munn, Pub.: Elsevier Science & Technology Books, 7th Edition, 2009.

Reference Books:

1. Mineral Processing Design and Operations: An Introduction, Ashok Gupta and Denis Yan, Elsevier, 2016.

Subject Code: MM2P003	Name: Process control and instrumentation laboratory	L-T-P-C: 0-0-3-2

Prerequisite: None

Part I

1. Temperature sensing: thermocouple and RTD.
2. Temperature measurement instrumentation: proportional controller, introduction to a PID controller.
3. Load and torque measurement cell.
4. Macroscopic strain measurements: LVDT and strain gauge.
5. Flow and pressure measurements: flow meters
6. RC circuits frequency response, Nyquist plots and Bode plots
7. Power control using Arduino and relays

Part II

1. Measurements, errors, precision and accuracy
2. Basics of data acquisition and programming using Labview
3. SCADA
4. Statistical techniques of data analysis
5. Calibration of optical microscope and introduction to digital image correlation.
6. Feature extraction and automatic image analysis.

Part III (optional)

A mini project to make a simplistic instrument that aids the existing facilities.

Text Books:

6. E. Doeblein, Measurement systems: Application and Design, Mc-Graw Hill higher education, 5th Edition, 2003
1. F.H. Raven, Automatic Control Engineering, McGraw-Hill, 1961

Reference Books:

2. P. Dransfield, Engineering Systems and Automatic Control, Prentice Hall, 1968
3. B.C. Nakra and K.K. Chaudhry, Instrumentation, Measurement and Analysis, Tata McGraw Hill, 1985
4. D.P. Eckeman, Industrial Instrumentation, Wiley Eastern, 1985

Subject Code: MM2P004	Name: Physical Metallurgy Laboratory	L-T-P-C: 0-0-3-2
Prerequisite:		

Experiments

1. Introduction to crystal structures, microstructures and structure determination techniques
2. Metallography of metallic materials
3. Effect of cooling rate during solidification on microstructure of metallic materials
4. Jominy end quench test
5. Recovery, recrystallization in brass specimens
6. Precipitation hardening – Al Cu alloys (quenching + ageing + hardness)
7. Effect of vacancy concentration on electrical resistivity
8. Annealing, normalizing and quenching of high carbon steels
9. Demonstration of the validity of Hall-Petch equation through experiments on copper

Text Books:

1. R. Abbaschian, L. Abbaschian, R. E. Reed-Hill, Physical metallurgy principles, 4th edition, Cengage learning, 2013

Reference Books:

1. N. E. Woldman, Physical metallurgy laboratory manual, Tradd Street Press, 2026

Subject Code: MM2L008	Name: Advances in Nanoscience and Nanotechnology	L-T-P-C: 3-0-0-3
Prerequisite: None		

Module 1 (Introduction) (5 hours)

Classification of Nanomaterials: Features of nanosystems; Characteristic length scale of materials and their properties; quantum dots, nanowire/tube, thin-films and nanocomposites;

Module 2 (Physics of nanomaterials) (10 hours)

Quantum effects in nanomaterials: Electron confinement in infinitely deep square well; Confinement in 1-D, 2-D and 3-D; Idea of quantum well structure; Variation of density of states and band-gap as a function of length-scale;

Module 3 (Characterization) (12 hours)

Structure and characterization of Nanomaterials: Basics of crystallography; X-Ray Diffraction; Scanning electron microscopy; Transmission Electron microscopy; Scanning probe microscopy, Spectroscopy techniques: Raman; IR spectroscopy, XPS

Mechanical and Functional characterization: Functional properties: Electrical, optical, magnetic and electronic properties and their characterization;

Module 4 (Synthesis) (10 hours)

Synthesis of Nanomaterials: Ball-milling; Thermo-mechanical processing; Physical vapour deposition; chemical vapour deposition; Electron-beam lithography; Thin films; Introduction to microfabrication techniques; Sol-Gel Processing, Self assembly; Lithographic techniques

Module 5 (Carbon nanostructure) (5 hours)

Carbon nano-structures: Fullerene, carbon nanotubes: single walled and multi-walled nanotubes; Graphene, Diamond like carbon films.

Text Books:

7. Nanostructures and Nanomaterials: Synthesis, Properties and Applications, G. Cao and Y. Wang, World Scientific Publishing Co., London, 2011.
8. Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers and Architects, Daniel L. Schodek, Paulo Ferreira, Michael F. Ashby, Butterworth-Heinemann, 2009.
9. Nanomaterials: Synthesis, Properties and Applications, Second Edition, A.S Edelstein, R.C Cammaratra, CRC Press.
10. Nanomaterials: Mechanics and Mechanisms, K.T. Ramesh, Springer, 2009.

Reference Books:

1. Introductory Nanoscience: Physical and Chemical Concepts, Masaru Kuno, Garland Science, 2011