Malaviya National Institute of Technology Jaipur

Revised Curriculum of M. Tech. (Metallurgical and Materials Engineering)

M. Tech I Semester

With effect from 2021-2022 Session

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	21MTT-501	Advanced Metallurgical Thermodynamics	PC	Theory	3	3	0	0
2.	21MTT-502	Materials Characterization	PC	Theory	3	3	0	0
3.	21MTT-504	Structure-Properties of Materials	PC	Theory	3	3	0	0
4.		Program Elective-I	PE	Theory	3	3	0	0
5.		Program Elective-II	PE	Theory	3	3	0	0
6.	21MTP-503	Metallurgical Laboratory	PC	Lab	2	0	0	4
					17			
List of Electives								
1.	21MTT-801	Advances in Heat Treatment	E-1	Theory	3	3	0	0
2.	21MTT-802	Corrosion and Its Prevention	E-1	Theory	3	3	0	0
3.	21MTT-803	Joining of Materials	E-1	Theory	3	3	0	0
4.	21MTT-804	Nanomaterials: Processing and Properties	E-2	Theory	3	3	0	0
5.	21MTT-805	Physical Metallurgy of Alloy Steels	E-2	Theory	3	3	0	0
6.	21MTT-806	Properties and Processing of Polymers	E-2	Theory	3	3	0	0

L=Lecture hours/week; **P**=Practical hours/week; **T**=Tutorial hours/week

M. Tech II Semester

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	21MTT-505	Advanced Physical Metallurgy	PC	Theory	3	3	0	0
2.	21MTT-506	Composite Materials	PC	Theory	3	3	0	0
3	21MTT-507	Mechanical Behavior of Materials	PC	Theory	3	3	0	0
4.		Program Elective-I	PE	Theory	3	3	0	0
5.		Program Elective-II	PE	Theory	3	3	0	0
6.		Program Elective-III	PE	Theory	3	3	0	0
					18			
List of Electives								
1.	21MTT-807	Advanced Ceramics and Glasses	E-3	Theory	3	3	0	0
2.	21MTT-808	Extraction of Metals	E-3	Theory	3	3	0	0
3.	21MTT-809	Fracture and Failure Analysis	E-1	Theory	3	3	0	0
4.	21MTT-810	Functional Materials	E-3	Theory	3	3	0	0
5.	21MTT-811	Light Metals and Alloys	E-1	Theory	3	3	0	0
6.	21MTT-812	Non-Destructive Testing and Evaluation	E-2	Theory	3	3	0	0
7.	21MTT-813	Powder Metallurgy and Particulate Materials Processing	E-2	Theory	3	3	0	0
8.	21MTT-814	Secondary Steel Making	E-2	Theory	3	3	0	0
9.	21MTT-815	Surface Engineering	E-1	Theory	3	3	0	0
10.	21MTT-816	Transport Phenomena in Materials Processes	E-3	Theory	3	3	0	0

M. Tech III Semester

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	21MTD-601	Dissertation-I	PC	-	10	0	0	20
2.	21MTS-602	Seminar *	PC	-	2	0	0	4

**** In lieu of seminar, interested students may be encouraged to do an internship in an industry/research organization for 4-8 weeks during summer vacation after Semester-II and will present a seminar in semester-III.***

M. Tech IV Semester

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1.	21MTD-603	Dissertation-II	PC	-	12	0	0	24

L=Lecture hours/week; **P**=Practical hours/week; **T**=Tutorial hours/week

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-501
Course Name	**:**	Advanced Metallurgical Thermodynamics
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Core
Prerequisites	**:**	none

Course Contents

Unit-1

Review of Thermodynamics - First, second and third laws of thermodynamics, concepts of entropy, Maxwell's relations, Clausius-Clayperon equation.

(**No. of Lectures: 08)**

Unit-2

Solutions - Solution models, regular, sub-regular, cluster variation models, multi-parameter models, quasi-chemical theory, statistical thermodynamics, multi-component systems.

(**No. of Lectures: 07)**

Unit-3

Equilibrium Concepts - Unary, binary, and multi-component systems, phase equilibria, the evolution of phase diagrams, metastable phase diagrams, calculation of phase diagrams, thermodynamics of defects.

(**No. of Lectures: 08)**

Unit-4

Thermodynamics of Phase Transformations - Melting and solidification, precipitation, eutectoid, massive, spinodal, martensitic, order-disorder transformations and glass transition, first and second-order transitions.

(No. of Lectures: 08)

Unit-5

Heterogeneous Systems - Equilibrium constant, Ellingham diagrams and their application to commercially important reactions, Porbaix Diagram, introduction to computational tools for thermodynamic equilibrium.

(No. of Lectures: 05)

Recommended Readings

Text Books

1. A. Ghosh, Textbook of Materials & Metallurgical Thermodynamics, Prentice Hall India, 2002.
2. D. A. Porter and K. E. Easterling, and M. Y. Sherif, Phase Transformations in Metals and Alloys, CRC Press, 3rd Ed. (Indian reprint), 2009.
3. A. Ghosh, H. S. Ray, Principles of Extractive Metallurgy, New Age Int.(P) Ltd., New Delhi, 1991.
4. R. A. Swalin, Thermodynamics of Solids, 2nd Ed., Wiley, New York, 1972.
5. S. K. Roy, Metallurgical Thermodynamics, Universities Press- IIM, 2019.
6. D. R. Gaskell and D. E. Laughlin, Introduction to Thermodynamics of Materials, 6th Ed., CRC Press Taylor and Francis Group, 2018.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-502
Course Name	**:**	Materials Characterization
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Core
Prerequisites	**:**	none

Course Contents

Unit-1

Optical Microscopy - Principle of the optical microscope, components of the microscope, the concept of resolution and magnification, specimen preparation for microscopic examination: sectioning and mounting, grinding, polishing, etching, determination of grain size and volume fractions of the phases present in the microstructure. (**No. of Lectures: 06)**

Unit-2

X-ray Diffraction (XRD)- X-ray diffraction, structure factor, indexing of XRD, determination of phases, lattice parameters, crystallite size, and residual stresses. (**No. of Lectures: 06)**

Unit-3

Electron Microscope (EM) - Principle and optics of scanning electron microscope (SEM) and Transmission electron microscope (TEM), types of electron sources, image formation, resolving power, specimen preparation techniques, applications of EMs. Electron beam-specimen interaction: contrast mechanism, bright-field image, and dark-field image, selected area diffraction (SAD), indexing of SAD pattern, texture analysis. (**No. of Lectures: 10)**

Unit-4

Micro and Surface Analysis - Basic principle and applications of X-ray photoelectron spectroscopy (XPS), auger electron spectroscopy (AES), energy dispersive spectroscopy (EDS), wavelength dispersive spectroscopy (WDS), scanning probe microscope, electron backscattered diffraction (EBSD). (**No. of Lectures: 06)**

Unit-5

Spectroscopy – UV Visible spectroscopy, X-ray fluorescence, infrared spectroscopy, and Raman spectroscopy. (**No. of Lectures: 03)**

Unit-6

Thermal Analysis - Basic principles of thermogravimetry analyzer (TGA), differential thermal analyzer (DTA), differential scanning calorimeter (DSC), dilatometer, etc. Interpretation of curves obtained from TGA/ DSC/ dilatometer for various materials etc. (**No. of Lectures: 05)**

Recommended Readings

Text Books

1. B. D. Cullity and S. R. Stock, Elements of Diffraction, 3rd Ed (Indian), Pearson, Noida, India, 2016.
2. S. Zhang, L. Li, and A. Kumar, Materials Characterization Techniques, CRC Press, New York, 2009.
3. D. Brandon and W. D. Kaplan, Microstructural Characterization of Materials, 2nd Ed., Wiley, 2008.

Reference Books

1. D. B. Williams and C. Barry Carter, Transmission Electron Microscopy, 2nd Ed., Springer, 2009.
2. J. Goldstein, Scanning Electron Microscopy and X-ray microanalysis, 3rd Ed., Springer, 2007.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-504
Course Name	**:**	Structure-Properties of Materials
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Core
Prerequisites	**:**	none

Course Contents

Unit-1

Fundamental characteristics of metals, ceramics, and polymers, coordination number, atomic structure, crystal structure, crystalline defects.

(**No. of Lectures: 08)**

Unit-2

Evaluation of mechanical properties.

(**No. of Lectures: 07)**

Unit-3

Microstructure and low-temperature strength, microstructure and high-temperature strength - structure-property relationships in super-alloys for high-temperature applications, microstructure, and low-temperature fracture, microstructure, and high-temperature.

(**No. of Lectures: 08)**

Unit-4

Effects of composition, processing, and structure on properties of irons and steels, effect of low temperature and high temperature on strength, the evolution of microstructure in steel products – rail steel, steel sheet, cast-iron.

(**No. of Lectures: 06)**

Unit-5

Effects of composition, processing, and structure on properties of non-ferrous alloys – Al, Cu, Ni, Ti, Zn, Mg.

(**No. of Lectures: 07)**

Recommended Readings

Text Books

1. K. M. Ralls, T. H. Courtney, and J. Wulff, Introduction to Materials Science and Engineering, John Wiley, 1976.
2. T. H. Courtney, Mechanical Behavior of Materials, McGraw-Hill, 1990.
3. R. W. Hertzberg, R. P. Vinci, J. L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, 5th edition, John Wiley, 2012.

Reference Books:-

1. ASM Handbook, Volume20: Materials Selection and Design, CRC Press, 1997.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-801
Course Name	**:**	Advances in Heat Treatment
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-1)
Prerequisites	**:**	none

Course Contents

Unit-1

Furnaces,basics of heat treatment, review on different types of heat treatment techniques, heat treatment process variables, the effect of heating and cooling on properties of steel, quenching technology, high-pressure gas quenching, applications of vacuum oil quenching.

(**No. of Lectures: 09)**

Unit-2

Recovery, recrystallization, and grain growth, TTT curves, and CCT diagram and its significance to heat treatment.

(**No. of Lectures: 08)**

Unit-3

Hardness and hardenability of steels and methods of determination, case hardening processes for steels (induction hardening, carburizing, nitriding, boronizing, carbonitriding), thermo-mechanical treatments, precipitation hardening (Maraging steel, PH stainless steel, Al-Cu based alloys), vacuum treatments, vacuum carburizing**.**

(**No. of Lectures: 07)**

Unit-4

Heat treatment of special steels like high speed steels, maraging steels, spring steels, ball bearing steels, stainless steels heat treatment defects and remedial measures.

(**No. of Lectures: 06)**

Unit-5

Heat treatment of some important non-ferrous metals such as aluminium, titanium, nickel, etc.

(**No. of Lectures: 06)**

Recommended Readings

Text Books

1. T. V. Rajan, C. P. Sharma, A. Sharma, Heat Treatment: Principles, Prentice Hall of India Pvt. Ltd., New Delhi,1994.
2. S. K. Mandal, Heat Treatment of Steels, McGraw Hill Education (NOIDA, India), 2017.
3. V. Singh, Heat treatment of Metals, Standard Publisher Distributors, 1998.
4. V. Raghvan, Physical Metallurgy: Principles and Practice, 3rd edition, Prentice Hall of India Publishing, 2015.

Reference Book

1. W. H. Cubberly, ASM Metals Handbook, 9th edition, Volume 4, 1981.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-802
Course Name	**:**	Corrosion and its Prevention
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-1)
Prerequisites	**:**	none

Course Contents

Unit-1

Relevance & importance of corrosion studies, costs of corrosion, expressions for corrosion rate. (**No. of Lectures: 02)**

Unit-2

Electrochemical & thermodynamic principles of corrosion, electrode kinetics, its application to experimental observations, activation, and concentration polarization, graphical representation of kinetic data, determination of E_{corr} and I_{corr} from potentiodynamic polarization curve, passivity & electrochemical behaviour of active-passive metals & alloys.

(**No. of Lectures: 14)**

Unit-3

Different forms of corrosion: Uniform, galvanic, intergranular, pitting, crevice, dealloying, stress corrosion cracking, corrosion fatigue, hydrogen embrittlement, high temperature corrosion. (**No. of Lectures: 10)**

Unit-4

Corrosion prevention: Selection of proper materials, development of suitable alloys, design improvement, modification of environment, cathodic & anodic protection, corrosion & its prevention, coating. (**No. of Lectures: 06)**

Unit-5

Case studies related to combatting corrosion in industries. (**No. of Lectures: 04)**

Recommended Readings

Text Books

1. L. L. Shrier, R. A. Jarmon and G.T. Bursteir, Corrosion: Vol. I & II, Butterworth & Heinemann publications, Great Britain, 1994.
2. D. Talbot and J. Talbot, Corrosion Science and Technology, CRC Press, London, 2019.
3. M. G. Fontana, Corrosion Engineering, Tata McGraw-Hill, 3rd Ed. (seventh reprint), 2008.
4. D. A. Jones, Principles and Prevention of Corrosion, Prentice-Hall, 1996.

Reference Books

1. P. R. Roberge, Corrosion engineering: principles and practice, McGraw-Hill, 2008.
2. V. S. Sastri, E. Ghali, and M. Elboujdaini, Corrosion prevention and protection: Practical solutions, John Wiley and Sons, 2007.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-803
Course Name	**:**	Joining of Materials
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-1)
Prerequisites	**:**	none

Course Contents

Unit-1

Introduction - Principle, theory, and classification of joining processes: Mechanical joining adhesive bonding, and welding, surface requirements for joining of metals.

(**No. of Lectures: 04)**

Unit-2

Basic Joining Processes - Principles and applications of gas welding, arc welding, thermit welding, resistance welding, spot welding, pressure welding, principles of brazing, soldering.

(**No. of Lectures: 08)**

Unit-3

Advanced Welding Processes - GTAW, GMAW, SMAW, electro-slag welding, plasma arc welding, electron beam welding, laser beam welding, ultrasonic welding, explosive welding, underwater welding, diffusion bonding, friction stir welding, 3-D printing.

(**No. of Lectures: 12)**

Unit-4

Metallurgical Aspects of Welding -Responses of materials to welding (structure of the welded joint, welding stresses and distortion, heat treatment of parent metals and welds, solidification cracking, reheat cracking), welding defects, and detection techniques.

No. of Lectures: 06)

Unit-5

Joining of specific Metals and Alloys - Welding metallurgy of carbon and alloy steels, cast irons, stainless steels, Al, Cu, Mg, and Ti-based alloys, and dissimilar metal/alloy combinations by diffusion bonding, glass-metal, and glass-ceramic seals.

(**No. of Lectures: 06)**

Recommended Readings

Text Books

1. R. S. Parmar, Welding Engineering and Technology, Khanna Publishers, 2004.
2. S. Kou, Welding Metallurgy, Wiley and Sons, 2005.
3. H. Cary and S. Helzar, Modern Welding Technology, Pearson Prentice Hall, 2004.

Reference Books

1. L. Jeffus, Welding: Principles and Application, Delmar Cengage Learning, 2007.
2. R.W. Messler, Joining of Materials and Structures, Elsevier (Butterworth-Heinemann), 2004.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-804
Course Name	**:**	Nanomaterials: Processing and Properties
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-2)
Prerequisites	**:**	Materials Science

Course Contents

Unit-1

Introduction to Nanomaterials - Length scales, surface area/volume ratio of micron to nanoscale materials, the importance of nanoscale and technology, examples of inspiration from nature and ancient history, top-down and bottom-up approaches, classification of nanomaterials, the effect of particle size on mechanical properties, thermal properties, electrical properties, magnetic properties, optical properties, and chemical reactivity. Nanowires, nanoclusters, nanobelts, and quantum dots/wells. (**No. of Lectures: 08)**

Unit-2

Fabrication of Nanomaterials - Top-down approaches-lithography, mechanical alloying, severe plastic deformation, bottom-up approaches-physical vapour deposition, chemical vapour deposition, molecular beam epitaxy, colloidal or wet chemical route, electrodeposition, green chemistry route, sol-gel method, atomic layer deposition. Synthesis, purification, properties, and applications of carbon nanotubes (CNT). Synthesis, properties, and applications of graphene. Synthesis, properties, and applications of nanowires. (**No. of Lectures: 08)**

Unit-3

Fabrication of Nanocomposites - Polymer matrix nanocomposites filled with CNT, graphene, nanowires, clay nanoparticles, metal matrix nanocomposites. (**No. of Lectures: 06)**

Unit-4

Characterization of Nanomaterials - Applications of X-ray diffraction, optical spectroscopy, surface area analysis (BET method), light scattering method, scanning electron microscope, transmission electron microscope, scanning probe microscopy- atomic force microscope and scanning tunneling microscope, X-ray photoelectron spectroscopy, nanoindentation. (**No. of Lectures: 08)**

Unit-5

Applications of Nanomaterials - Nanofluids, hydrogen storage, solar energy, antibacterial coating, self-cleaning coating, nano textiles, biomedical field, water treatment, automotive sector, catalysts. (**No. of Lectures: 06)**

Recommended Readings

Text Books

1. M. F. Ashby, P. J. Ferreira and D. L. Schodek, Nanomaterials, Nanotechnologies and Design: An Introduction for Engineersand Architects, Elsevier, 2009.
2. R. K. Goyal, Nanomaterials and Nanocomposites: Synthesis, Properties, Characterization Techniques and Applications, CRC Press, 2017.
3. B. S. Murty, P. Shankar, B. Raj, B. B. Rath, and J. Murday, Textbook of Nanoscience and Nanotechnology, University Press (I) Pvt. Ltd, 2013.

Reference Books

1. G. L. Hornyak, H. F. Tibbals, and J. Dutta, Introduction to nanoscience and nanotechnology, CRC Press, 2009.
2. C. P. Poole, Jr. and F. J. Owens, Introduction to Nanotechnology, Wiley, 2003.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-805
Course Name	**:**	Physical Metallurgy of Alloy Steels
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-2)
Prerequisites	**:**	Physical Metallurgy/ Material Science

Course Contents

Unit 1

Advantages of alloy steels over plain carbon steels, classification of alloy steels, physical metallurgy of alloy tool steels of different varieties, Microstructural variation with heat treatment and its impact on properties and application of steels such as cold work tool steel, hot work tool steels, water hardening tool steels, shock-resisting tool steels, and high-speed steels.

(**No. of Lectures: 12)**

Unit 2

Physical metallurgy of advanced steel e.g. dual-phase steel, IF steel, high manganese steel, TRIP steel, TWIP steel, high boron steels.

(**No. of Lectures: 08)**

Unit 3

Physical metallurgy of stainless steel and their classification, embrittlement in ferritic stainless steel, sensitization, and stabilization in austenitic stainless steel; stabilized austenitic alloys, physical metallurgy of discaloy, and A286 with their specific applications.

(**No. of Lectures: 13)**

Unit 4

Strengthening mechanisms and influence of reverted austenite on the properties of maraging steels.

(**No. of Lectures: 03)**

Recommended Readings

Text books

1. T. V. Rajan, C. P. Sharma, and A. Sharma, Heat treatment: principles, Prentice Hall of India Pvt. Ltd., New Delhi, 1994.

Reference book

1. V. Singh, Heat treatment of metals, Standard Publisher Distributors, 1998.
2. G. Krauss, Steels processing, structure, and performance, 2nd edition, ASM International, 2015.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-806
Course Name	**:**	Properties and Processing of Polymers
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-2)
Prerequisites	**:**	Materials Science

Course Contents

Unit-1

Introduction to Polymers - Thermoplastics, thermosets, high-performance polymers, liquid crystal polymers, polymer blends & alloys, shape memory polymers, thermoplastic elastomers, thermoset elastomers, molecular weight distributions, roles of additives, and glass transition temperature. (**No. of Lectures: 08)**

Unit-2

Factors Affecting Properties - Effect of chemical composition, types of bonds, structures, and degree of crystallinity on the mechanical, thermal, electrical, barrier, and rheological properties of polymers. Effect of molecular weight, crosslinking, fillers, and additives on transition temperatures. (**No. of Lectures: 08)**

Unit-3

Processing Techniques - Injection molding**,** special injection molding processes (multi-component injection molding, co-injection molding, gas-assisted injection molding, injection-compression molding, reaction injection molding, liquid silicone rubber injection molding), extrusion, blow molding, rotational molding, thermoforming, calendering, foaming.

(**No. of Lectures: 10)**

Unit-4

Additive manufacturing techniques - Stereo lithography, fused filament fabrication, selective laser sintering, other 3D printing techniques, etc. (**No. of Lectures: 05)**

Unit-5

Characterization Techniques: Melt flow index, limiting oxygen indexer, Thermogravimetry analyzer, differential scanning calorimetry, dynamic mechanical analyzer. (**No. of Lectures: 05)**

Recommended Readings

Text Books

1. V. K. Stokes, Introduction to Plastics Engineering, John Wiley & Sons Ltd, UK, 2020.
2. R. J Crawford and P. J Martin. Plastics Engineering, 4th edition, Elsevier, UK. 2020.
3. T. A. Oswald and G. Menges, Materials Science of Polymers for Engineers, 3rd edition, Hanser Publications, Cincinnati, USA, 2012.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTP-503
Course Name	**:**	Metallurgical Laboratory
Credits	**:**	2 **(L -** 0 **T -** 0 **P -** 4**)**
Course Type	**:**	Core
Prerequisites	**:**	None

Course Contents

Students should perform at least eight experiments.

1. Study of optical microscopy and its application in microstructural characterization of materials.
2. Metallographic sample preparation techniques for microstructural characterization.
3. Microstructural examination of ferrous systems (grain size measurements, phase analysis, inclusions rating, etc.).
4. Microstructural examination of non-ferrous systems.
5. Quenching and tempering of steel.
6. Jominy end quench test.
7. Heat treatment of ferrous and non-ferrous alloys.
8. Microstructural characterization using electron microscope.
9. X-ray diffraction and its applications in materials characterization (Miller indexing of XRD pattern).
10. Thermal analysis and its application in materials characterization.
11. Study and measurement of mechanical behaviour of materials.
12. Study and measurement of corrosion behaviour of materials.

Recommended Readings

Text Books

1. G. F. Vander Voort, Metallographic Principles and Practice, ASM International, USA, 1999.

Reference Books

1. ASM Handbook, Volume 9: Metallography and Microstructures, 2020.
2. ASM Handbook, Volume 10: Materials Characterization, 2020.
3. ASM Handbook, Volume 8: Mechanical Testing and Evaluation, 2020.
4. ASM Handbook, Volume 13A: Corrosion: Fundamentals, Testing, and Protection, 2020.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-505
Course Name	**:**	Advanced Physical Metallurgy
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Core
Prerequisites	**:**	Basics of Material Science

Course Contents

Unit-1

Structure of solids, experimental tools, and techniques, solidification of pure metals- the concept of free energy, stability, equilibrium concept in unary system, effect of pressure on equilibrium transformations. (**No. of Lectures: 07)**

Unit-2

Plastic deformation of pure metals– mechanisms (slip & twin), critical resolved shear stress, single crystal tensile test (FCC), theoretical strength of ideal crystal. Imperfections in solids including fundamentals of dislocations, diffusion in solids. (**No. of Lectures: 07)**

Unit-3

Solidification of binary alloys –free energy of solutions, free energy vs composition diagrams, chemical potential. (**No. of Lectures: 07)**

Unit-4

Phase rules, phase diagrams, evolution of phase diagrams, solid-state transformations - precipitation hardening, pearlitic, bainitic& martensitic transformation. thermodynamics of heterogeneous systems, stress and strain induced transformations. (**No. of Lectures: 08)**

Unit-5

Heat treatment of steel, TTT diagram, effect of alloying elements, hardenability, application of physical metallurgy - strengthening mechanism, strength vs. toughness (ductility), thermo mechanical processing, micro alloyed steel, ultra-high strength steel, superalloy, control of texture. (**No. of Lectures: 07)**

Recommended Readings

Text Books

1. V. Raghavan. Solid state phase transformations, PHI of India Pvt. Ltd., New Delhi, 1987.
2. D. A. Porter and K. E. Esterling, Phase transformation in metal and alloys, Chapman Hall, 1992.
3. R. E. Smallman and A. H. W. Ngan, Physical metallurgy and advanced materials engineering, 7th edition, Butterworth-Heinemann, 2011.

Reference Books

1. R. Abbaschian, L. Abbaschian, R. E. Reed-Hill. Physical Metallurgy Principles, 4th edition, Cengage Learning, 2009.
2. G. Gottstein. Physical foundations of materials science, Springer, 2004.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-506
Course Name	**:**	Composite Materials
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Core
Prerequisites	**:**	Materials Science

Course Contents

Unit-1

Overview- Introduction and importance of composite materials over other materials. (**No. of Lectures: 04)**

Unit-2

Reinforcements- Role of reinforcements, types of reinforcement: fibers, particulates, and whiskers, types of fibers: glass, carbon, boron, organic and ceramic fibers, comparison of fibers, and non-oxide particulates (SiC and WC).
(**No. of Lectures: 06)**

Unit-3

Interfaces- Wettability, the effect of surface roughness, crystallographic nature of the interface, interactions at the interface, type of bonding (mechanical, physical, and chemical) at the interface, role of interfaces. (**No. of Lectures: 06)**

Unit-4

Classification and Strengthening of Composite- Classification of composites based on matrices, types and orientation of fibers. Micromechanics: strengthening by fibers or particulates, mechanism of deformation in fiber reinforced composites, the influence of fiber length, its orientation, and volume fraction on composite properties. Mechanisms of toughening in composites. (**No. of Lectures: 10)**

Unit-5

Processing, Properties, and Applications– Metal matrix composites, polymer matrix composites, ceramic matrix composites, nanocomposites, merits and demerits of nanocomposites compared to composites. (**No. of Lectures: 10)**

Recommended Readings

Text Books

1. K. K. Chawla. Composite Materials: Science & Engineering, 3rd edition, Springer, New York, 2013.
2. A. K. Kaw. Mechanics of Composite Materials, 2 edition, CRC Press, New York, 2005.
3. D. Hull, T. W. Clyne.An Introduction to Composite Materials, Cambridge University Press, 1996.

Reference Books

1. M. M. Schwartz. Composite Materials: Properties, Non-destructive Testing and Repair, Prentice Hall, New Jersey, 1996.
2. D. A. Colling and T. Vasilos. Industrial Materials: Polymers, Ceramics and Composites, Vol. 2, Prentice Hall, N. Jersey, 1995.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-507
Course Name	**:**	Mechanical Behavior of Materials
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Core
Prerequisites	**:**	none

Course Contents

Unit-1

Imperfections in crystal structures - point, line, and surface imperfections, dislocations – types and sources of dislocations, dislocation theory, grain boundaries, and stacking faults. (**No. of Lectures: 08)**

Unit-2

Elastic and plastic deformation – Elastic and plastic behavior of materials, deformation under plane strain and plane stress condition, theory of yielding, slip and twinning, mechanisms of plastic deformation in single crystals and polycrystalline materials; super-plasticity, deformation under plane strain and plane stress condition, strengthening mechanisms in crystalline solids. cold work and annealing of metals. (**No. of Lectures: 10)**

Unit-3

Fracture - Mode and mechanism of fracture, Griffith theory, the significance of DBTT, determination of K_{IC}, concepts of fracture toughness and formability, fracture characterization, and failure analysis. (**No. of Lectures: 08)**

Unit-4

Micro and surface analysismechanical testing - Tensile testing: Engineering stress-strain curve, true stress-strain curve, tensile properties, and metallurgical factors affecting tensile properties. Hardness testing, impact testing, fatigue behavior & testing, creep behavior & testing: Typical creep curve, creep mechanisms, factors affecting creep behavior

(**No. of Lectures: 06)**

Unit-5

Mechanical behavior of non-metallic materials - structure and deformation of polymers, the concept of super-lattice dislocations in the intermetallic, concept of charge associated with dislocations in ceramics. (**No. of Lectures: 04)**

Recommended Readings

Text Book

1. A. K. Bhargava, and C. P. Sharma, Mechanical Behavior and Testing of Materials, PHI Learning (P) Ltd., 2011.
2. G. E. Dieter, Mechanical Metallurgy, McGraw Hill Education, Indian Edition, 2017.
3. R. W. Hertzberg, R. P. Vinci, and J. L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, John Wiley & Sons, 2012.

Reference Books

1. R. Abbaschian, R. E. Reed-Hill, and L. Abbaschian, Physical Metallurgy Principles, Cengage Learning India Pvt. Ltd., 2009.
2. M. N. Shetty, Dislocations and Mechanical Behavior of Materials, PHI Learning (P) Ltd., 2013.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-807
Course Name	**:**	Advanced Ceramics and Glasses
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-3)
Prerequisites	**:**	Introduction to Engineering Materials

Course Contents

Unit-1

Introduction to ceramic structures, point defect equilibria in ceramics, novel processing techniques for ceramic powders, deformation behaviour, and toughening of ceramics. (**No. of Lectures: 08)**

Unit-2

Refractories, structural ceramics, ceramic cutting tools, ceramic coatings, wear components, high strength, and high-temperature components, ceramics for sensors, advanced functional ceramics, advanced ceramics for strategic applications. (**No. of Lectures: 10)**

Unit-3

Glassy State; kinetic and thermodynamic criteria for glass formation, nucleation and crystal growth in glasses, nucleation through micro miscibility, nucleating agents, properties and applications of glass-ceramics, use of Na_2O-SiO_2 and Na_2O-CaO- SiO_2 phase diagrams in glass manufacture, types and properties of glasses. (**No. of Lectures: 10)**

Unit-4

Thermal endurance of glass, toughening of glasses, strength and fracture behavior of glass, surface tension, effect of temperature and composition on the physical properties of glasses, defects in glass. (**No. of Lectures: 08)**

Recommended Readings

Text Books

1. B. Carter and G. Norton, Ceramic Materials: Science and Engineering, Springer, 2007.
2. W. Höland and G. H. Beall, Glass Ceramic Technology. John Wiley & Sons, 2012.
3. W. D. Kingery, H. K. Bowen and D. R. Uhlman, Ceramic Science and Technology, John Wiley and Sons, 1976.
4. C. J. Brinker, D. E. Clark, and D. R. Ulrich, Better Ceramics through Chemistry, North Holland, 1984.
5. R. C. Buchanan and M. Dekker, Ceramic Materials for Electronics, Inc. 1986.

Reference Books:-

1. B. Karmakar, Functional Glasses and Glass-Ceramics: Processing, Properties and Applications. Butterworth-Heinemann, 2017.
2. F. F. Y. Wang, Ceramic Fabrication Processes, Academic Press, 1976.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-808
Course Name	**:**	Extraction of Metals
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-3)
Prerequisites	**:**	None

Course Contents

Unit-1

Pyro-metallurgy - Principles of pyro-metallurgy, unit operations in pyro-metallurgy, calcination, roasting, smelting, converting, and fire-refining, advancements in pyrometallurgy. **(No. of Lectures: 07)**

Unit-2

Hydrometallurgy - Principles of hydro-metallurgy, leaching, solvent-extraction, iron exchange, cementation, advancements in hydrometallurgy. **(No. of Lectures: 07)**

Unit-3

Electro-Metallurgy - Principles of electrolysis, electro-winning and electrorefining, advancements in electro-metallurgy. **(No. of Lectures: 07)**

Unit-4

Extraction Processes of major Non-ferrous metals - Aluminium, copper, nickel, zinc, lead, titanium, magnesium, uranium, gold and silver, lithium including material preparation and refining etc. Properties and uses of metals and their alloys for industrial applications. **(No. of Lectures: 09)**

Unit-5

Heat, mass and overall energy balance in metallurgical operations. **(No. of Lectures: 06)**

Recommended Readings

Text Books

1. A. Ghosh and H. S. Ray, Principles of Extractive Metallurgy, Wiley, 1991.
2. H. S. Ray, R. Sridhar and K. P. Abraham, Extraction of Nonferrous Metal, East-West Press Pvt Ltd, 2008.
3. R. D. Pehlke, Unit Processes in Extractive Metallurgy, American Elsevier, Mishigan, 1973.
4. A. Ghosh and A. Chatterjee, Iron Making and Steelmaking: Theory and Practice, PHI Learning Pvt. Ltd., 2008

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-809
Course Name	**:**	Fracture and Failure Analysis
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-1)
Prerequisites	**:**	Students should have a fundamental understanding of mechanical behavior especially elastic and plastic deformation.

Course Contents

Unit-1

Basic Concepts in Fracture Mechanics - The geometry of stress and strain, elastic deformation, plastic, and elastoplastic deformation, the concept of catastrophic failure, Brittle fracture: Griffiths theory, ductile fracture, probabilistic aspects of fracture mechanics. (**No. of Lectures: 08)**

Unit-2

Mechanics of Fracture- Static Loading - Elastic fields – Analytical solutions yielding near a crack front – Irwin's approximation-plastic zone size-Dugdaale model – J integral and its relation to crack opening displacement, strain energy release and stress intensity factor, evaluation of fracture toughness of different materials: size effect & control.

(**No. of Lectures: 08)**

Unit-3

Failure Analysis of Fatigue Fracture - Fundamental sources of failures- deficiency in design, empirical relation describing crack growth by fatigue – life calculations for a given load amplitude-effects of changing the load spectrum-effects of environment, microstructural analysis of fatigue failures, some case studies in the analysis of fatigue failures.

(**No. of Lectures: 08)**

Unit-4

Failure Analysis of Creep Rupture - Fracture at elevated temperature: Time-dependent mechanical behavior, stress rupture, microstructural changes during creep, mechanism of creep deformation and creep deformation maps, prediction of time to rupture, creep-fatigue interaction, some case studies in the analysis of creep failures. (**No. of Lectures: 08)**

Unit-5

Failure Analysis of Corrosion and Wear: Failure due to erosion and corrosion. (**No. of Lectures: 04)**

Recommended Readings

Text Books

1. P. Kumar, Elements of Fracture Mechanics, 2nd Ed., Wheelers Publishing Co. Ltd India, 2010.
2. R. J. Sanford, Principles of Fracture Mechanics, Printice Hall, USA, 2003.
3. G. E. Dieter, Mechanical Metallurgy, 3rd edition, McGraw Hill Book Co., N. Delhi (Indian Edition), 2017.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-810
Course Name	**:**	Functional Materials
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-3)
Prerequisites	**:**	None

Course Contents

Unit-1

Introduction, phase transformations and relations between crystal structure and functional properties; piezoelectricity, ferroelectricity, magnetism, and energy storage etc. (**No. of Lectures: 06)**

Unit-2

Applications in dielectric, piezoelectric, ferroelectric, magnetic, semiconducting, electronic, electromagnetic interference/radio frequency, optical devices (light-emitting diodes, organic solar cells, smart windows), transistors, sensors, energy storage or solar harvesting functions, etc. (**No. of Lectures: 12)**

Unit-3

Ionic conductors in batteries, sensors, and fuel cells. (**No. of Lectures: 06)**

Unit-4

Materials in medical applications: stainless steel alloys, cobalt alloys, titanium-based alloys, polymer and its composites, bio-resorbable materials, bio-ceramics, bioactive glasses, calcium phosphate, naturally derived biomaterials, bio-functional coatings**.** (**No. of Lectures: 12)**

Recommended Readings

Text Books

1. D. D. L. Chung. Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Applications, Vol. 2, World Scientific Pub., 2010.
2. S. Ramakrishna, M. Ramalingam, T. S. Sampath Kumar. Biomaterials: A Nano Approach, CRC Press, 2013.
3. S. Banerjee and A. K. Tyagi. Functional Materials: Preparation, Processing and Applications by, 1st edition, Elsevier, USA, 2012.
4. J. Kilner, S. Skinner, S. Irvine, P. Edwards, Functional Materials for Sustainable Energy Applications, Woodhead Publishing, 2012.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-811
Course Name	**:**	Light Metals and Alloys
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-1)
Prerequisites	**:**	None

Course Contents

Unit-1

General introduction, production, processing, and properties of light metals and alloys**,** applications. (**No. of Lectures: 05)**

Unit-2

Physical and mechanical metallurgy of aluminium and aluminium alloys, nomenclature of Al alloys, classification of aluminium alloys, wrought and cast aluminium alloys, work hardening, annealing and age hardening of aluminium alloys. (**No. of Lectures: 08)**

Unit-3

Physical and mechanical metallurgy of magnesium and magnesium alloys, alloying behaviour, classification, deformation behaviour, effect of crystallographic texture on properties. (**No. of Lectures: 08)**

Unit-4

Physical and mechanical metallurgy of titanium and titanium alloys, classification of titanium alloys, α alloys, α/β alloys, β alloys, titanium aluminides. (**No. of Lectures: 08)**

Unit-5

Beryllium and Li alloys, rapid solidification, metallic glasses, quasicrystals, mechanical alloying, future aspects and challenges. (**No. of Lectures: 07)**

Recommended Readings

Text Books

1. I. J. Polmear, Light alloys: From Traditional Alloys to Nanocrystals, 4th edition, Elsevier, 2006.
2. G. Gottstein, Physical Foundations of Materials Science, 1st edition, Springer, 2004.
3. G. Lütjering and J. Williams, Engineering Materials and Processes: Titanium, 2nd edition, Springer, 2007.
4. K. U. Kainer, Magnesium Alloys and Technology, 1st edition, Wiley, 2003.

Reference Books

1. ASM Handbook, Volume 9: Metallography and Microstructures, 2020.
2. ASM Handbook, Volume 2A: Aluminium Science and Technology, 2020.
3. ASM Handbook, Volume 2: Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, 2020.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-812
Course Name	**:**	Non-Destructive Testing and Evaluation
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-2)
Prerequisites	**:**	None

Course Contents

Unit-1

Introduction - Need for inspection, types of the inspection system, quality of inspection, reliability of defect detection, and benefits of NDT examination. (**No. of Lectures: 05)**

Unit-2

Visual Inspection - Basic principles, physical aids used for visual inspection and applications, liquid penetrant inspection: Physical principles, procedures of testing, penetrant testing materials, penetrant testing methods, applications and limitations. (**No. of Lectures: 06)**

Unit-3

Magnetic Particle Testing - Principle of MPT, magnetization techniques, procedure used for testing a component, equipment used for MPT, Eddy current testing: Basic principles, techniques used for ECT, applications and limitations. (**No. of Lectures: 06)**

Unit-4

Radiography - Basic principles, electromagnetic radiation sources, effect of radiation in film, radiographic imaging, inspection techniques, micro-computed tomography, applications and limitations. (**No. of Lectures: 05)**

Unit-5

Ultrasonic Testing - Basic principles of sound beam, ultrasonic transducers, type of display, inspection methods A, B and C scanning modes, identification of defects, immersion testing, applications and limitations. (**No. of Lectures: 06)**

Unit-6

Acoustic Emission Testing (AET) - Principles, technique, instrumentation and applications, miscellaneous tests, reliability in NDT, statistical methods for quality control. (**No. of Lectures: 05)**

Unit-7

Leak Testing - Basic principles and application. (**No. of Lectures: 03)**

Recommended Readings

Text Books

1. B. Raj, T. J. Kumar and M Thavasimuthu, Practical Non-Destructive Testing, ASM Intl, 2nd edition, 2002.
2. B. Hull and V. John, Non Destructive Testing, Springer;New York, 1st edition, 1988.
3. S. H. Avner, Introduction to Physical Metallurgy, McGraw-Hill Inc., US, 2nd edition, 1974.
4. A. V. K. Suryanarayana, Testing of Metallic Materials, PHI, New Delhi, 2007.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-813
Course Name	**:**	Powder Metallurgy and Particulate Materials Processing
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-2)
Prerequisites	**:**	None

Course Contents

Unit-1

Introduction - Historical background of particulate materials involving metal powders and ceramics. Powder Production: General principles of mechanical, atomization, chemical, and electrolytic method of metal and alloy powders production, production of nano-powders, Mechanical alloying. (**No. of Lectures: 06)**

Unit-2

Powder characterization - Chemical composition, microstructure, size and size distribution, shape, surface area, flow rate, apparent and tap density, compressibility, pyrophoricity and toxicity of metallic powders. (**No. of Lectures: 06)**

Unit-3

Powder conditioning - Annealing, mixing, and blending and their mechanics, powder mixers. (**No. of Lectures: 03)**

Unit-4

Cold compaction and sintering - Cold compaction: compaction in rigid dies, uniaxial and biaxial compaction, cold isostatic pressing, mechanical and hydraulic presses, basic stages of sintering and mechanisms involved, solid-state and liquid state sintering, reaction sintering, sintering of ferrites, spark plasma sintering, microwave sintering, sintering furnaces, various sintering atmospheres, additive manufacturing. **No. of Lectures: 09)**

Unit-5

Hot compaction - Hot pressing, powder compact extrusion, and powder compact forging, hot isostatic pressing, ECAP, powder rolling. (**No. of Lectures: 06)**

Unit-6

Applications - Porous PM parts viz. bushes, filters, and bioimplants, dispersion strengthened materials, cemented carbides. (**No. of Lectures: 06)**

Recommended Readings

Text Books

1. P. C. Angelo and R. Subramanian, Powder metallurgy: science, technology and applications, PHI Learning (P) Ltd., 2008.
2. B. K. Datta, Powder metallurgy: an advanced technique of processing, engineering materials, second edition, PHI Learning (P) Ltd., 2014.
3. A. Upadhyaya and G.S. Upadhyaya, Powder metallurgy: science, technology and materials, Universal Press, 2011.
4. A. K. Sinha, Powder metallurgy, DhanpatRai publication, 2021.

Reference Books

1. R. M. German, Powder Metallurgy Science Princeton, N.J.: Metal Powder Industries Federation, 1994.
2. R. H. T. Dixon and A. Clayton, Powder Metallurgy for Engg. Machinery Publishing, Brighton, UK, 1996.
3. F.V. Lenel, Powder Metallurgy: Principles & Applications, Princeton, N.J.: Metal Powder Industries Federation, 1980.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-814
Course Name	**:**	Secondary Steel Making
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-2)
Prerequisites	**:**	Steel Making

Course Contents

Unit-1

Basic principles of primary steel making - Raw material, theory of slags, mechanism of removal of common impurities like Si, C, Mn, P and S. Slag-metal and gas-metal reactions in steel making, importance of secondary steel making. (**No. of Lectures: 08)**

Unit-2

Concept of cleanliness of steels - Inclusion in steels- its different types and genesis, dissolved gasses, tramp and residual elements in steels and their effect on steel properties. (**No. of Lectures: 04)**

Unit-3

Secondary steel making principles and practices - Objectives and techniques adopted in secondary steel making, ladle metallurgy, inert gas stirring and its merits, ladle furnace, principles of deoxidation, desulphurization and inclusion control, injection metallurgy and its usefulness, ladle refining technique with synthetic slag practice, vacuum degassing of steel and related processes. (**No. of Lectures: 12)**

Unit-4

Refining of steel by remelting under vacuum - CEVAM process, principles of ESR & VAR processes ladle metallurgy as secondary refining process - Vacuum arc degassing, ASEA-SKF process, production of stainless steel through VOD, AOD and CLU processes. (**No. of Lectures: 06)**

Unit-5

Tundish metallurgy - Evaluation of tundish hydrodynamic performances, solidification phenomena, conventional, continuous and near net shape casting phenomena. (**No. of Lectures: 06)**

Recommended Readings

Text Books

1. A. Ghosh, Secondary Steelmaking: Principles & Applications, CRC Press, 2001.
2. A. Ghosh, and A. Chatterjee, Iron Making and Steelmaking: Theory and Practice, PHI Learning (P) Ltd., 2008.
3. D. Mazumdar, A first course in Iron and Steel Making, Universities Press (P) Ltd., 2015.
4. A. K. Chakrabarti, Steel Making, PHI Learning (P) Ltd., 2007.

Reference Books

1. J. M. Camp, The Making, Shaping and Treating of Steel, Hard Press Publishing, 2012.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-815
Course Name	**:**	Surface Engineering
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-1)
Prerequisites	**:**	None

Course Contents

Unit-1

Surface degradation, introduction to tribology and corrosion of surfaces, wear: types of wear, roles of friction and lubrication, and corrosion: an overview of different forms of corrosion, Introduction to surface engineering, the importance of substrate. (**No. of Lectures: 08)**

Unit-2

Chemical and electrochemical polishing, significance, specific examples, chemical conversion coatings, phosphating, chromating, chemical colouring, anodizing of aluminium alloys, thermochemical processes -industrial practices. (**No. of Lectures: 08)**

Unit-3

Surface pre-treatment, deposition of copper, zinc, nickel and chromium - principles and practices, alloy plating, electrocomposite plating, electroless plating of copper, nickel phosphorous, nickel-boron; electroless composite plating; application areas, properties, test standards (ASTM) for assessment of quality of deposits. (**No. of Lectures: 07)**

Unit-4

Definitions and concepts related to physical vapour deposition (PVD), evaporation, sputtering, ion plating, plasma nitriding, process capabilities, chemical vapour deposition (CVD), metal organic CVD, plasma assisted CVD, thermal spraying, conventional shot peening, LASER shock pinning, severe surface deformation, surface mechanical alloying, LASER nitriding, specific industrial applications. (**No. of Lectures: 07)**

Unit-5

Surface characterization techniques: Film thickness measurements using optical techniques, corrosion testing of coatings, evaluation of mechanical properties of thin films, microstructural characterization of coatings and thin films, wear and erosion testing of coatings. (**No. of Lectures: 06)**

Recommended Readings

Text Books

1. T. S. Sudarshan. Surface Modification Technologies - An Engineer's guide, Marcel Dekker, New York, 1989.
2. I. M. Hutchings. Tribology: Friction and Wear of Engineering Materials, Butterworth-Heinemann, 1992.
3. C. D. Varghese. Electroplating and Other Surface Treatments - A Practical Guide, TMH, 1993.
4. T. Burakowski and T. Wierzchon. Surface Engineering of Metals, CRC Press, 1998.

Reference Books

1. W. Batchelor, L. N. Lam and M. Chandrasekaran. Materials Degradation and its Control by Surface Engineering, Imperial college press, 1999.
2. S. S. Hosmani, P. Kuppusami, and R. K. Goyal. An Introduction to Surface Alloying of Metals, Springer, 2014.

Online resources- https://nptel.ac.in

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre	**:**	Department of Metallurgical and Materials Engineering
Course Code	**:**	21MTT-816
Course Name	**:**	Transport Phenomena in Materials Processes
Credits	**:**	3 **(L -** 3 **T -** 0 **P -** 0**)**
Course Type	**:**	Elective (E-3)
Prerequisites	**:**	Fundamentals of Thermodynamics & Kinetics of Material

Course Contents

Unit-1

Fluid Dynamics - Continuum fluids, laminar and turbulent flow, Newton's law of viscosity, introduction to non-newtonian fluids, pressure and temperature dependency of viscosity, viscosity of gases at low density, fundamental concepts in momentum transfer, shell balance, governing equations and relevant boundary conditions, equations of change for isothermal systems – Navier-Stokes equation, use of equations of change to set up steady state flow problems with newtonian fluids, friction factor, microscopic mass, momentum and energy balance for isothermal systems, Bernoulli's equation, Euler's equations and its integration to obtain Bernoulli's equation.

(**No. of Lectures: 12)**

Unit-2

Heat Transfer - Physical origins and rate equations, introduction to conduction, conduction rate equation, thermal properties of matter, heat diffusion equation, boundary and initial conditions, one-dimensional, steady-state conduction, the plane wall, radial systems, conduction with thermal energy generation, concept of heat transfer coefficient, forced and free convection, aspects of radiative heat transfer.

(**No. of Lectures: 12)**

Unit-3

Mass Transfer - Fick's Law of diffusion, analogy with heat transfer, shell mass balances, boundary conditions, applications, conductive mass transfer, mass transfer coefficients, applications, correlations.

(**No. of Lectures: 09)**

Unit-4

Similarity of three transport processes and its applications, momentum transfer.

(**No. of Lectures: 03)**

Recommended Readings

Text Books

1. R. B. Bird, W. E. Stewart, and E. W. Lightfoot, Transport Phenomena, 2nd Revised Edition, John Wiley, 2007.
2. T. L. Bergman, A. S. Lavine, F. P. Incropera, and D. P. DeWitt, Fundamentals of Heat and Mass Transfer, 8th Edition, John Wiley, 2006.
3. Y. V. C. Rao, Heat Transfer, University Press, 2001.
4. A. K. Mahanty, Rate Processes in Metallurgy, PHI, 2009.

Online resources- https://nptel.ac.in