

Materials engineering examinations

Group A - Examinations (six of seven required)

21-Mat-A1 Thermodynamics (10-MET-A1)

Phase relationships and phase rule. First, second and third laws of thermodynamics, enthalpy and heat balances, entropy, free energy, and chemical equilibrium. Solution chemistry and solution models, chemical potential, relationships between phase diagrams and thermodynamic properties. Thermochemical analyses of materials processes.

Textbooks (most recent edition is recommended):

- D.R. Gaskell: Introduction to Metallurgical Thermodynamics, CRC Press
- R. De Hoff: Thermodynamics in Materials Science, CRC Press

21-Mat-A2 Materials Transport Phenomena

TEXT RE-ORDERED (NO CHANGE)

Transport equations for momentum, heat and mass transfer. Understanding of transport phenomena in materials processes, e.g., transfer in casting processes, fluid flow in piping networks, mass diffusion in doping of semiconductors. Boundary conditions describing process/transport phenomena. Interphase transport: gas-solid, gas-liquid, liquid-liquid, and liquid-solid applied to materials systems. Materials processing operations: mixed flow, plug flow, residence time. Radiation heat transfer: black and grey body, emissivity and view factors. Development of relevant mathematical models.

Textbooks (most recent edition is recommended):

- D.R. Gaskell: An Introduction to Transport Phenomena in Materials Engineering, Prentice-Hall

Supplementary:

- A. Powell IV: Transport Phenomena in Materials Engineering, MIT Open Courseware.
<http://ocw.mit.edu/courses/materials-science-and-engineering/3-185-transportphenomena-inmaterials-engineering-fall-2003/>

21-Mat-A3 Structure and Characterization of Materials

REWRITTEN

Characteristics of crystal structures for steel and metallic, ceramic, and polymeric structures. Uses and limitations of elemental analysis (i.e., EDS, XPS, XRD) and standard materials characterization techniques, i.e., optical and electron microscopy (SEM) and thermal analysis (i.e., DTA, DSC, TGA) to determine or analyze crystal structure, microstructure, and surface morphology.

Textbooks (most recent edition is recommended):

- D.D. Brandon and W.D. Kaplan: Microstructural Characterization of Materials, Wiley
- Y. Leng: Materials Characterization: Introduction to Microscopic and Spectroscopic Techniques, Wiley-VCH
- ASM Handbook Committee: Metals Handbook, Volume 10: Materials Characterization, ASM International
- J.F. Shackelford: Introduction to Materials Science for Engineers, MacMillan Publishing Company

21-Mat-A4 Deformation Behaviour and Properties of Materials (10-MET-A5) REWRITTEN

Elastic and plastic deformation. Strengthening mechanisms in materials including dislocation interactions, slip and twinning in crystalline solids, polymer crosslinking and degree of crystallinity. Fracture mechanisms. Introductory fracture mechanics. High temperature (creep) deformation. Cyclic stresses and fatigue crack propagation. Thermal properties. Electronic properties.

Textbooks (most recent edition is recommended):

- T.H. Courtney: Mechanical Behaviour of Materials, Waveland Press
- G. Dieter: Mechanical Metallurgy, McGraw-Hill
- W.D. Callister and D.G. Rethwisch: Materials Science and Engineering: An Introduction, Wiley
- R.W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, John Wiley & Sons

21-Mat-A5 Phase Transformations and Thermal Treatment

BROADENED SCOPE

Binary phase diagrams. Annealing and heat treatment techniques for stress relief, recovery, recrystallization, grain growth, and precipitation hardening. Crystallization kinetics, diffusion, and nucleation and growth phenomena in metals. Amorphous materials, glass transition temperature, Tg. Time-temperature-transformation (TTT) diagrams.

COMBINES 12-MTL-A5 & 12-MTL-A6 & 10-MET-A6

Textbooks (most recent edition is recommended):

- M.Y.A. Sherif, D.A. Porter and K.E. Easterling: Phase Transformations in Metals and Alloys, CRC Press
- W.D. Callister and D.G. Rethwisch: Materials Science and Engineering: An Introduction, Wiley

21-Mat-A6 Materials Selection and Design for Materials Processing

WAS 12-MTL-B16. HAS BEEN SIMPLIFIED. MAY BE A COMMON EXAM WITH 22-MEC-B8

The process of materials selection for different design criteria and constraints. The importance of shape and processing variables. Use of materials indices and materials selection charts. Sustainable materials selection and design. Materials life cycle assessment, including end-of-life potential.

Textbooks (most recent edition is recommended):

- M. Ashby: Materials Selection in Mechanical Design, Butterworth-Heinemann

21-Mat-A7 Environmental Degradation of Materials

12-MTL-B11/10-MET-A7 WITH ADDITIONAL SCOPE FOR NON-METALS. STILL PRIMARILY CORROSION.

Fundamental aspects of environmental degradation of metals (corrosion), ceramics, and polymers, with an emphasis on aqueous environments. Topics include: Basic corrosion theory. Electrochemical corrosion theory. Stress assisted corrosion. Protective coatings. Corrosion inhibitors. Cathodic and anodic protection.

Textbooks (most recent edition is recommended):

- M. Kutz: Handbook of Environmental Degradation of Materials, Elsevier
- W.D. Callister and D.G. Rethwisch: Materials Science and Engineering: An Introduction, Wiley
- S.A. Bradford: Corrosion Control, CASTI
- R.W. Revie and H.H. Uhlig: Corrosion and Corrosion Control: An Introduction to Corrosion Science and Engineering, Wiley

Group B - Optional examinations (four required)

21-Mat-B1 Hydrometallurgy and Electrometallurgy WAS 12-MTL-B2 / 10-MET-B2

Unit processes of hydrometallurgy: acid, alkaline and pressure leaching. Thermodynamic and kinetic aspects. Pourbaix diagrams. Purification of leach liquors by ion exchange, solvent extraction and selective precipitation operations. Solid-liquid separation techniques. Principles of electrometallurgy. Recovery of metal values by cementation, electrowinning and refining from aqueous solutions. Electrolyte preparation, cell potential, effect of additives. Hydrogen precipitation methods. Application of processes for the recovery of copper, nickel, zinc, cobalt, gold and uranium.

Textbooks (most recent edition is recommended):

- M.L. Free: Hydrometallurgy: Fundamentals and Applications, TMS

21-Mat-B2 Pyrometallurgy NEW - ELEMENTS FROM 12-MTL-B1/10MET-B1

Principles of mineral processing: comminution, physical separation techniques, flotation, dewatering. Pyrometallurgical operations including roasting, smelting, converting, and refining. Refractory design and selection. Process analysis based on flow sheets, heat and mass balances. Environmental impact of processing operations.

Textbooks (most recent edition is recommended):

- R.E. Reed-Hill, Abbaschian, R. and Abbaschian, L.: Physical Metallurgy Principles, Cengage Learning

21-Mat-B3 Ironmaking and Steelmaking (10-MET-B3) MINOR CHANGES

Thermodynamics and kinetics of iron and steelmaking reactions. Theory and practice of ironmaking including direct reduction processes. Primary steel refining. Ladle metallurgy including desulfurization, deoxidation, inert gas and vacuum treatment. Secondary refining processes including AOD, VAD, and VOD. Continuous casting. Chemical properties of fluxes, slags and refractories. Analysis of new and emerging steelmaking technologies including new processes for reduced energy consumption and pollution.

Textbooks (most recent edition is recommended):

- B. Deo and R. Boom: Fundamentals of Steelmaking Metallurgy, Prentice-Hall
- E.T. Turdogan: Fundamentals of Steelmaking, Woodhead Publishing Ltd

21-Mat-B4 Physical and Extractive Metallurgy of Non-Ferrous Metal and Alloys

COMBINES 10-MET-B4/12-MTL-B4 & 10-MT-B7/12-MTL-B7

Properties, structure and processing of non-ferrous metals and alloys: Aluminum, Copper, Titanium, Nickel, Cobalt, Magnesium and Zinc. The application of principles of thermodynamics, kinetics, and transport phenomena to the extraction and refining of nonferrous metals using pyrometallurgical processes. Production of copper, nickel, lead, and zinc from sulphides. Converting and flash smelting operations. Production of aluminum and magnesium using fused salt electrolysis. Reduction cell operation. Production of refractory metals by chlorination and purification. Recent developments in non-ferrous pyrometallurgy. Environmental impact.

Textbooks (most recent edition is recommended):

- C.B. Gill: Non-Ferrous Extractive Metallurgy, John Wiley and Sons
- W.F. Smith: Structure and Properties of Engineering Alloys, McGraw-Hill
- ASM Handbook Committee: Metals Handbook for Non-Ferrous Alloys, Properties and Selection: Nonferrous Alloys and Special-Purpose Materials, Volume 2, ASM International

21-Mat-B5 Physical Metallurgy and Fabrication of Iron and Steel

COMBINES 10-MET-B5/12-MTL-B5 & 10-MET-B6/12-MTL-B6

Properties, structure and processing of iron-carbon alloys (Fe-C system and transformation of austenite to ferrite, cementite and/or martensite) including plain carbon steels, alloyed steels, stainless steels, tool steels, and cast irons. Heat treatment (annealing and normalizing, cold working and process annealing, tempering, austempering and martempering). Surface hardening and modification. Casting methods (ingot, continuous, sand, die, investment casting). Hot working (hot rolling, extrusion, and forging). Bending and sheet metal operations (roll bending and forming, shearing operations, stretch forming and drawing, and hydroforming). Welding (arc welding, friction stir welding, and laser welding).

Textbooks (most recent edition is recommended):

- E.P. DeGarmo, J.T. Black, and R.A. Kohser: Materials and Processes in Manufacturing, Wiley
- W.F. Smith: Structure and Properties of Engineering Alloys, McGraw-Hill

Supplementary:

- ASM Handbook Committee: Metals Handbook Volume 4 – Heat Treating, ASM International
- ASM Handbook Committee: Metals Handbook Volume 1 – Properties and Selection: Iron, Steels and High Performance Alloys, ASM International

21-Mat-B6 Ceramic Materials

WAS 12-MTL-B8/10-MET-B8
NO CHANGE TO TEXT

Bonding in ceramics. Ceramic structures. Effect of chemical forces and structure on physical properties. Defects in ceramics. Diffusion and electrical conductivity. Phase equilibria. Sintering and grain growth. Mechanical properties: fast fracture, creep, slow crack growth and fatigue. Thermal stresses and thermal properties. Dielectric properties.

Textbooks (most recent edition is recommended):

- W.D. Kingery, H.K. Bowen, and D.R. Uhlmann: Introduction to Ceramics, Wiley

21-Mat-B7 Structure and Properties of Polymers

WAS 12-MTL-B9/10-MET-B9
REWRITTEN

Chain architecture: chain dimensions, Gaussian segment density distribution, polymer conformation. Molar mass determination: osmometry, light scattering, gel permeation chromatography, capillary viscometry. Polymer phase equilibria: solvent quality, polymer blending. Polymer structure/transitions: melting and glass transition temperatures, free volume. Crystallization: crystal structure, fractional crystallinity. Mechanical properties: testing methods, compliance, viscoelasticity, dynamic testing, time-temperature superposition, rubber elasticity. Polymer flow properties: viscosity, rheology, shear thinning, analysis of flow fields. Polymer processing techniques.

Textbooks (most recent edition is recommended):

- R.J. Young, and P.A. Lovell: Introduction to Polymers, CRC Press
- Alfred Rudin: The Elements of Polymer Science and Engineering, Academic Press

21-Mat-B8 Electrical, Optical, and Magnetic Materials and Devices

WAS 12-MTL-B10/10-MET-B10

Free electron theory, band theory: energy levels in solids, effective mass, Fermi-Dirac statistics. Semiconductors: effective mass, doping, activation, P-n junctions, field-effect transistors, and solar

cells. Dielectrics and polarization: dielectric materials, index of refraction, light-matter interactions, dielectric breakdown, piezoelectricity, ferroelectricity and pyroelectricity. Magnetism: field intensity, permeability, exchange interaction, saturation magnetization, magnetic domains and anisotropy, hysteresis loop. Superconductivity: Meissner effect, superconducting materials, critical field and current density, BCS theory.

REWRITTEN, OPTICAL DEVICES ADDED

Textbooks (most recent edition is recommended):

- L. Solyman and D. Walsh: Electrical Properties of Materials, Oxford University Press
- J. Livingston: Electronic Properties of Engineering Materials, Wiley

21-Mat-B9 Modeling and Simulation of Materials Processing NEW

Mathematical and physical modelling of processes employed in the production of materials; standard techniques of numerical analysis and their application to materials systems. The application of models to analyze, design and optimize materials production and/or usage.

Textbooks (most recent edition is recommended):

- C.I. Pruncu and J. Jiang, Modeling and Optimization in Manufacturing: Toward Greener Production by Integrating Computer Simulation, Wiley
- S. Alavi, Molecular Simulations: Fundamentals and Practice, Wiley

21-Mat-B10 Properties and Processing of Micro- and Nanomaterials

WAS 12-MTL-B14

Traditional microfabrication processes: lithography (photolithography, ebeam lithography), etching (wet vs. dry, isotropic vs. anisotropic), physical deposition (ebeam and sputtering), chemical deposition (CVD, PECVD, ALD), electrodeposition, oxidation, diffusion, ion implantation. Techniques: Lift-off, self-alignment, epitaxy. Yield and metrology.

REWRITTEN

Textbooks (most recent edition is recommended):

- J.D. Plummer, M.D. Deal, and P.B. Griffin: Silicon VLSI Technology: Fundamentals, Practice, and Modeling, Prentice-Hall

21-Mat-B11 Composite Materials

WAS 12-MTL-B17
REWRITTEN

Metals, polymers, ceramics, glass as matrix and fillers for various materials properties (PMC, CMC, MMC). Fabrication techniques considering particle and fiber reinforcement. Isostress and isostrain loading. Continuous, random, aligned, critical length, orientation of fillers. Failure modes and mechanisms and use in thermal, mechanical, optical, electrical, high-temperature applications.

Textbooks (most recent edition is recommended):

- K. K. Chawla: Composite Materials, Springer-Verlag
- W. D. Callister and D.G. Rethwisch: Materials Science and Engineering: An Introduction, Wiley

TOTAL EXAMINATION PROGRAM

PEO Syllabus of Examinations, 2012 Edition

MATERIALS ENGINEERING

PROFESSIONAL EXAMS – SPECIFIC TO MATERIALS ENGINEERING

GROUP A

12-Mtl-A1 Materials Thermodynamics

Phase relationships and phase rule. First, second and third laws of thermodynamics, enthalpy and heat balances, entropy, free energy, and chemical equilibrium. Solution chemistry and solution models, chemical potential, relationships between phase diagrams and thermodynamic properties. Thermochemical analyses of materials and electrochemical processes.

12-Mtl-A2 Transport Phenomena in Materials Engineering

Transport equations for momentum, heat and mass transfer. Thermodynamic and physical boundary conditions. Interphase mass transfer: gas-solid, gas-liquid, liquid-liquid, and liquid-solid applied to materials systems. Mathematical models. Radiation heat transfer: black and grey body, emissivity and view factors. Heat transfer in casting processes: mould properties, continuous casting. Reactor theory applied to materials operations: mixed flow, plug flow, residence time.

12-Mtl-A3 Structure and Characterization of Materials

Structure of crystalline and amorphous materials including polymers. Analytical methods to determine structure including optical, scanning and transmission electron microscopy, and diffraction techniques (including X-ray and electron diffraction). Defects in solids and dislocation theory. Grain boundaries. Introduction to phase equilibria and phase diagrams.

12-Mtl-A4 = 10-Met-A5 Mechanical Behaviour of Materials

Dislocation theory. Slip and twinning in crystalline solids. Strengthening mechanisms in materials. Mechanical properties and testing of materials. Crystallographic texture and anisotropy. High-temperature deformation response of crystalline solids. Failure mechanisms of materials (ductile and brittle failure, creep and creep fracture, fatigue crack propagation and failure, and stress corrosion cracking). Elements of fracture mechanics.

12-Mtl-A5 Phase Transformations of Metals, Glasses, and Ceramics

Phase diagrams. Diffusion and diffusional transformations in solids. Crystal interfaces and microstructure. Diffusionless transformations. Theory of transformation kinetics. Spinodal decomposition. Nucleation and growth processes, and solidification phenomena. Nucleation and growth kinetics. Precipitation hardening. Phase separation in glasses.

12-Mtl-A6 Thermal Treatment of Metals, Glasses, and Ceramics

Heat flow and precipitation. Strengthening of glasses by tempering and ion exchange, colloidal colors. Photosensitive and photochromic glasses. Recrystallization and grain growth. Solid-state sintering. Vitrification. Sintering with reactive liquid. Pressure sintering and hot pressing. Iron-carbon and non-ferrous alloy systems. Hardening of steel. Annealing of metals (recovery, recrystallization, grain growth, secondary recrystallization, and heat treatments based on these phenomena).

GROUP B

12-Mtl-B1 = 10-Met-B1 Mineral Processing

Sources and nature of metallic and industrial minerals of importance. Comminution techniques, size classification. Hydrocyclones, gravity and magnetic separations. Flotation: surface chemistry, reagents, analysis. Tailings disposal, water pollution control, closed circuit operation. Plant design, process analysis and optimization.

12-Mtl-B2 = 10-Met-B2 Hydrometallurgy and Electrometallurgy

Unit processes of hydrometallurgy: acid, alkaline and pressure leaching. Thermodynamic and kinetic aspects. Pourbaix diagrams. Purification of leach liquors by ion exchange, solvent extraction and selective precipitation operations. Solid-liquid separation techniques. Principles of electrometallurgy. Recovery of metal values by cementation, electrowinning and refining from aqueous solutions. Electrolyte preparation, cell potential, effect of additives. Hydrogen precipitation methods. Application of processes for the recovery of copper, nickel, zinc, cobalt, gold and uranium.

12-Mtl-B3 = 10-Met-B3 Ironmaking and Steelmaking

Thermodynamics and kinetics of iron and steelmaking reactions. Direct reduction processes. Blast furnace operations. Chemical properties of fluxes, slags and refractories. Converter processes and electric furnace steelmaking. Treatment of hot metal, ladle metallurgy including desulfurization, deoxidation, inert gas and vacuum treatment. Continuous casting. Secondary refining processes including AOD, VAD, VOD, VAR, and ESR. Analysis of new and emerging steelmaking technologies. Environmental control.

12-Mtl-B4 = 10-Met-B4 Non-Ferrous Extractive Metallurgy

The application of principles of thermodynamics, kinetics, and transport phenomena to the extraction and refining of non-ferrous metals using pyrometallurgical processes. Production of copper, nickel, lead, and zinc from sulphides. Converting and flash smelting operations. Production of aluminum and magnesium using fused salt electrolysis. Reduction cell operation. Production of refractory metals by chlorination and purification. Recent developments in non-ferrous pyrometallurgy. Environmental impact.

12-Mtl-B5 = 10-Met-B5 Metal Fabrication

Fundamentals of solidification: phase diagrams, cooling curves, cast structures, solidification shrinkage, molten metal characteristics. Casting methods including ingot casting, continuous casting, sand casting, die casting, investment casting, counter gravity, lost foam, mould casting, squeeze and semi-solid casting. Hot working: hot rolling, extrusion, and forging. Bending and sheet metal operations: roll bending and forming, shearing operations, stretch forming and drawing, hydroforming, and superplasticity. Powder metallurgy processes.

12-Mtl-B6 = 10-Met-B6 Physical Metallurgy of Iron and Steel

Diffusional and diffusionless transformations in plain carbon, alloy, stainless, and tool steels. Use of alloying elements in steels to produce enhanced properties – physical, mechanical, corrosion and oxidation resistance. Hardenability of steels and surface hardening and modification. Structure and properties of cast irons.

12-Mtl-B7 = 10-Met-B7 Physical Metallurgy of Non-Ferrous Metals and Alloys

Chemical compositions, classification, properties, and applications of aluminum, copper, titanium, nickel, cobalt, magnesium and zinc and their alloys. Refractory metals and alloys and structural intermetallics.

12-Mtl-B8 = 10-Met-B8 Ceramic Materials

Bonding in ceramics. Ceramic structures. Effect of chemical forces and structure on physical properties. Defects in ceramics. Diffusion and electrical conductivity. Phase equilibria. Sintering and grain growth. Mechanical properties: fast fracture, creep, slow crack growth and fatigue. Thermal stresses and thermal properties. Dielectric properties.

12-Mtl-B9 = 10-Met-B9 Structure and Properties of Polymers

Polymer phase equilibria: solvent quality, polymer blending. Mechanical properties: testing methods, compliance, viscoelasticity, dynamic testing, time-temperature superposition, mastercurve, rubber elasticity, crazing. Polymer flow properties: viscosity, rheology, shear thinning, analysis of flow fields. Polymer processing techniques.

12-Mtl-B10 = 10-Met-B10 Advanced Electronic Materials

Band theory: energy levels in solids, effective mass, Fermi-Dirac statistics. Semiconductors: doping, activation, diffusion, P-n junctions, and solar cells. Dielectrics and polarization: capacitance, dielectric materials, Lorentz field, dielectric breakdown, piezoelectricity, ferroelectricity and pyroelectricity. Magnetism: field intensity, permeability, exchange interaction, saturation magnetization, magnetic domains and anisotropy, hysteresis loop. Superconductivity: Meissner effect, superconducting materials, critical field and current density, BCS theory. Metals: contact potential, Seebeck and thermocouple effect, thermoelectrics, electromigration.

12-Mtl-B11 = 10-Met-A7 Corrosion and Oxidation

Basic corrosion theory. Electrochemical corrosion theory. Metallurgical cells. Environmental cells. Stress assisted corrosion. Materials selection. Protective coatings. Corrosion inhibitors. Cathodic and anodic protection. Oxidation.

12-Mtl-B12 Biomaterials and Biocompatibility

Physical, chemical and biological properties of different classes of materials used in medicine. Host and biomaterials responses and their evaluation. Biological testing of biomaterials. Applications of biomaterials in tissue and organ systems. Degradation of biomaterials in the biological environment. Host-implant reactions including wound healing response and inflammatory response. Physiological and biomechanical basis for soft-tissue implants. Design of modified biomaterials. Bulk and surface characterization of biomaterials. Applications of biomaterials in functional tissue engineering. Regulatory and ethical concerns dealing with the implementation and commercialization of biomaterials and medical devices.

12-Mtl-B13 Advanced Characterization of Materials

Crystalline and amorphous structure. Electronic structure of atoms. Atomic bonding, coordination, and packing. Symmetry in crystals and impact on mechanical properties. Optical microscopy, scanning electron microscopy, and transmission electron microscopy. X-ray diffraction. Analytical techniques including optical and X-ray spectroscopy, mass spectroscopy, and chromatography. Other advanced microscopy techniques such as focused ion-beam microscopy, scanning transmission electron microscopy, Auger electron spectroscopy, etc.

12-Mtl-B14 Nanomaterials

Physical chemistry of solid surfaces, zero, one and two dimensional nanostructures, special nanomaterials, nanostructures fabricated by different physical techniques. Characterization and properties of nanomaterials in electronics, biology, catalysis, quantum devices, energy and environment.

12-Mtl-B15 Joining of Materials

Principles of joining – classification of joining methods, engineering requirements, joining problems, surface science. Welding – weld geometry, heat transfer, energy sources, and welding of ferrous and non-ferrous alloys, metallurgy. Principles of brazing and soldering. Fabrication of metal-ceramic joints and diffusion bonding. Adhesives – thermoplastic and thermosetting, elastomers.

12-Mtl-B16 = 07-Mec-B8 (in part) Materials Selection and Failure Analysis

Decision-making process for materials selection in design – motivation, cost, specification. Selection for mechanical properties – strength, toughness, stiffness, fatigue, creep, and temperature resistance. Selection for surface durability – corrosion, wear, materials processing. Failure analysis – procedural steps, failure types and characteristics, analytical techniques, types and characteristics of defects in castings and processing.

12-Mtl-B17 Composite Materials

Introduction to design of fibre-matrix composites, effect of fibre architecture (such as aspect ratio, volume fraction), fibre orientation, type of matrices and interfacial bonding on mechanical and thermal behaviour of composites. Fracture mechanics, fabrication, and applications of engineering composites materials.

12-Mtl-A1 Materials Thermodynamics**Prime Text**

Gaskell, David, Introduction to the Thermodynamics of Materials (5th ed.). Taylor and Francis Inc., 2008. ISBN: 9781591690436. Chapters 2, 3, 6, 8-14.

Supplementary References

De Hoff, Robert, Thermodynamics in Materials Science. Second edition, CRC Press, 2006. ISBN: 979849340659

Lee, H. G., Chemical Thermodynamics for Metals and Materials. Imperial College Press, 2001. ISBN: 1-86094-X.

Rosenquist, T., Principles of Extractive Metallurgy. Second edition, Tapir Academic Press, 2004. ISBN: 9788251919227.

12-Mtl-A2 Transport Phenomena in Materials Engineering**Prime Text**

Poirier, D.R., and Geiger, G.H., Transport Phenomena in Materials Processing. Wiley, 1998. ISBN: 0873392752. Chapters 1, 2, 3, 6-15.

Supplementary References

Gaskell, D.R., Transport Phenomena in Materials Engineering. Prentice-Hall, 1991. ISBN: 97800234070208.

Guthrie, R.I.L., Engineering in Process Metallurgy. Oxford University Press, 1992. ISBN: 0198563671.

Powell IV, A., "Transport Phenomena in Materials Engineering". MIT Open Courseware. <http://ocw.mit.edu/courses/materials-science-and-engineering/3-185-transport-phenomena-in-materials-engineering-fall-2003/>.

Szekely, J. and N.J. Themelis, Rate Phenomena in Process Metallurgy, Wiley-Interscience, 1971. ISBN: 0471843030.

12-Mtl-A3 Structure and Characterization of Materials**Prime Texts**

Reed-Hill, R.E. and R. Abbaschian, Physical Metallurgy Principles. (4th edition) Cengage Learning, Stamford, CT, 2009. ISBN 0495082546. Chapters 1-4, 6, 7 and 11.

Callister WD and Rethwisch DG (2009) Materials Science and Engineering: An Introduction, 8th Ed. Wiley. Chapters 14, 15.

Supplementary References

Kingery, W.D., H.K. Bowen, and D.R. Uhlmann, Introduction to Ceramics. (2nd edition) Wiley, New York, 1976. ISBN 0471478601. Chapters 2-5 and 7.

Callister WD and Rethwisch DG (2009) *Materials Science and Engineering: An Introduction*, 8th Ed. Wiley. Chapters 2,3.

ASM Handbook Vol. 9 - Metallography and Microstructures. 2004.

ASM Handbook Vol. 10 - Materials Characterization. 1986.

12-Mtl-A4 Mechanical Behaviour of Materials

Prime Text

Hertzberg R.W., Deformation and Fracture Mechanics of Engineering Materials. (4th edition) John Wiley, New York, 1996. ISBN 0-471-01214-9. Chaps 1-5, 7-13.

Supplementary References

Courtney, T.H., Mechanical Behaviour of materials, 2nd Edition. 2000. ISBN #0-070-28594-2.

Dieter, G., Mechanical Metallurgy. (3rd edition) McGraw-Hill Book Co., New York, 1986. ISBN 0070168938.

ASM Handbook Vol. 8. Mechanical Testing and Evaluation. 2000.

12-Mtl-A5 Phase Transformations of Metals, Glasses, and Ceramics

Prime Text

Porter, D.A., Easterling, K.E. and Sherif M.Y. *Phase Transformations in Metals and Alloys* (3rd ed.) CRC Press, 1992. Chapters 1-6.

Kingery, W.D., H.K. Bowen, and D.R. Uhlmann, Introduction to Ceramics. (2nd edition) Wiley, New York, 1976. ISBN 0471478601. Chapter 8-10.

Supplementary References

Reed-Hill, R.E. and R. Abbaschian, Physical Metallurgy Principles. (4th edition) Cengage Learning, Stamford, CT, 2009. ISBN 0495082546. Chapters 8, 9, 14-16, and 18-20.

ASM Handbook Vol. 2 - Properties and Selection Nonferrous Alloys and Special-Purpose Materials. 1990.

ASM Handbook Vol.1 - Properties and Selection Irons, Steels and High-Performance Alloys. 1990.

12-Mtl-A6 Thermal Treatment of Metals, Glasses, and Ceramics

Prime Text

Krauss, G., Steels: Heat Treatment Processing Principles. ASM International, 1990. Chapters 5-11.

Kingery, W.D., H.K. Bowen, and D.R. Uhlmann, Introduction to Ceramics. (2nd edition) Wiley, New York, 1976. ISBN 0471478601. Chapter 8-10.

Brooks, C.R., Heat Treatment Structure and Properties of Nonferrous Alloys. American Society for Metals, Metals Park, OH, 44073, USA, 1984. Chapters 1-3.

Supplementary References

ASM Handbook Vol. 4 - Heat Treating. 1991.

12-Mtl-B1 = 10-Met-B1 Mineral Processing

Prime Text

Napier-Munn, T. and B.A. Wills, Mineral Processing Technology. Butterworth-Heinemann, 2006. ISBN: 0750644508. Chapters 2-16.

Supplementary References

Kelly, E.G. and D.J. Spottiswood, Introduction to Mineral Processing. Wiley Interscience, 1992. ISBN-10: 0471033790.

Mular, A.L. and D. Halbe and D. Barrat, Mineral Processing Plant Design, Practice and Control. Society for Mining, Metallurgy and Exploration, 1992. ISBN: 0873352238.

12-Mtl-B2 = 10-Met-B2 Hydrometallurgy and Electrometallurgy

Prime Text

Jackson, E, Hydrometallurgical Extraction and Reclamation. Ellis Horwood Limited, 1986. Halstead Press, John Wiley & Sons. SBN: 0-7458-0048-3 and 0-470-2034-5. Chapters: 1, 2, 3, 4, 5.

Supplementary References

Habashi, F., Textbook of Hydrometallurgy. Les copies de la capitale inc., 1995. Distributed by Laval University Bookstore. ISBN : 2-980-3247-7-9.

Peters, E. G. L. Bolton, D.B. Dreisinger and B. Conard, Hydrometallurgy: Theory and Practice. TMS-AIME Press, 1992. ISBN: 0444986562.

Rosequist, T., Principles of Extractive Metallurgy. Tapir Academic Press, 2004. ISBN: 9788251919227.

12-Mtl-B3 = 10-Met-B3 Ironmaking and Steelmaking

Prime Text

Turdogan, E.T., Fundamentals of Steelmaking. Woodhead Publishing Limited, 1996. ISBN: 1861250045. Chapters: All.

Supplementary References

Fruehan, R.J., The Making Shaping and Treating of Steel. 11th edition, ironmaking Volume. AIST Publications, 1992. ISBN: 978-0-930767-03-7.

Fruehan, R.J., The Making Shaping and Treating of Steel. 11th edition, Steelmaking and Refining Volume. AIST Publications, 1992. ISBN: 978-0-930767-02-0.

Fruehan, R.J. and E.T. Turkdogan, Proceedings of the Ethem T. Turkdogan Symposium: Fundamentals and analysis of New and Emerging Steelmaking Technologies, Pittsburgh, 1994. The Metals and Materials Society, Iron and Steel Society

12-Mtl-B4 = 10-Met-B4 Non-Ferrous Extractive Metallurgy

Prime Text

Gill, C.B., Non-Ferrous Extractive Metallurgy. John Wiley and Sons, 1998. ISBN: 0894642642. Chapters: all.

Supplementary References

Davenport, W.G., Extractive Metallurgy of Copper. Pergamon Press, Oxford, 1994. ISBN: 0080421245.

Evans, J.W. and Z.C. Dejonghe, The Production of Inorganic Material. TMS Press, Warrendale, 2002. ISBN: 0873395417.

Rosenquist, T., Principles of Extractive Metallurgy. Tapir Academic Press, 2004. ISBN: 9788251919227.

12-Mtl-B5= 10-Met-B5 Metal Fabrication

Prime Text

DeGarmo, E. Paul, J.T. Black, and Ronald A. Kohser, Materials and Processes in Engineering, 10th Edition. 2007. ISBN: 0-470-05512-X. Chapters 4, 7, 13-19.

Supplementary References

Kapakjian, Serope and Steve Schmid, Manufacturing Engineering and Technology, 6th edition, Prentice Hall. 2009. ISBN # 0136081681.

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