

## **1(a). M.Sc. in Metallurgical and Materials Engineering**

### **Core Courses**

#### **MME-501      Mechanical Behaviour of Engineering Materials      (3+0)**

General properties of engineering materials: Normal and shear stress, Normal and shear strain, Hooke's law for isotropic materials, Tensile Strength and Tensile Stress, Stiffness in Tension - Young's Modulus, Resilience, The Poisson Effect, Toughness, Stress-Strain Curves, 3D stress states, Stress strain curves for engineering materials, Strain energy, Anisotropic materials and symmetry (Composite materials), Torsion, Bending and stretching properties.

Thermodynamics of Mechanical Response: Enthalpic Response, Entropic Response, Viscoelasticity, Stiffness, Strength, Bonding between atoms; energetic basis for linear elasticity, Thermal strain; origins of thermal strain, Rubber elasticity: entropic basis for non-linear elasticity.

Yield and Plastic Flow: Multiaxial Stress States, Effect of Hydrostatic Pressure, Effect of Rate and Temperature, Continuum Plasticity, The Dislocation Basis of Yield and Creep, Kinetics of Creep in Crystalline Materials.

Fracture: Atomistics of Creep Rupture, Fracture Mechanics - the Energy-Balance Approach, The Stress Intensity Approach, Fatigue.

#### **Recommended Books**

1. Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, Wiley 2012.
2. Joachim Roesler, Harald Harders, Martin Baeker, Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers, and Composites, Springer 2010

**MME-502 Characterization of Engineering Materials (3+0)**

Electrochemical and Radiochemical Analysis: Elemental and Functional Group Analysis.

Diffraction Methods: X-Ray Powder Diffraction. X-Ray Diffraction Residual Stress Techniques. High-Energy Synchrotron X-ray Diffraction (In-situ Analysis).

Electron Optical Methods: Analytical Transmission Electron Microscopy. Scanning Electron Microscopy. Scanning Tunneling microscopy, Atomic Force Microscopy, Piezo-Force Microscopy and other related techniques. Image Analysis. Electron Probe X-Ray Microanalysis. Low-Energy Electron Diffraction. Chromatography: Gas Chromatography. Mass Chromatography.

X-Ray Spectrometry. Mass Spectroscopy, FTIR spectroscopy, Raman spectroscopy, X-ray photo Electron Spectroscopy, Inductively Coupled Plasma. Atomic Emission Spectroscopy. Atomic Absorption Spectrometry.: Spark Source Mass Spectrometry. Gas Analysis by Mass Spectrometry.

**Recommended Books:**

1. Elton N. Kaufmann, Characterization of Materials, Wiley 2012
2. Brandon, D. and Kaplan, W. D., "Microstructural Characterisation of Materials", Wiley, 2nd Edition. 2008.
3. Wachtman, J. B., "Characterization of Materials, Butterworths-Heinemann, 2000 Loretto, M. H., "Electron Beam Analysis of Materials", 2<sup>nd</sup> Edition, Chapman and Hall, 1984
4. Flewitt P.E.J., Physical Methods for Material characterization, 2<sup>nd</sup> Edition, IOP, 2003

**MME-503 Corrosion and Corrosion Control (3+0)**

Overview of Corrosion Science and Corrosion Engineering, The function and role of a Corrosion Engineer, Strategic impact and cost of Corrosion damage, Corrosion Kinetics and Applications of Electrochemistry to Corrosion, Activation polarization, concentration polarization and combined polarization. Reference electrodes. Passivity and passivity of alloys, Mechanisms of growth and breakdown of passive films,

Corrosion failure, factors and Cells, Corrosion in soils and microbiologically influenced corrosion, Prediction Corrosion Behavior, Corrosion Rate Measurements,

Corrosion Testing, Exposure Techniques, Evaluation of Different Types of Corrosion

Corrosion Prevention Methods, Proper Materials Selection, Alteration of Environment, Design Considerations, Cathodic and Anodic Protection, Cathodic protection in Soils, Cathodic protection in Concrete, Sacrificial Cathodic Protection, Impressed Current Cathodic Protection, Inhibitors and Passivators, Protective Coatings, Coating Inspection and Testing,

High Temperature Corrosion, Pilling-Bedworth Ratio, Electrochemical and Morphological Aspects of Oxidation, Oxidation Kinetics, Effect of Alloying, Catastrophic Oxidation, Corrosion of Metals by Sulfur Compounds at High Temperatures, Practical High Temperature Corrosion Problems

**Recommended Books**

1. Pierre Roberge, Handbook of Corrosion Engineering 2/E, McGraw-Hill Professional 2012
2. Revie and Uhlig "Corrosion and Corrosion Control" Wiley 4th Ed. 2008
3. Fontana, M. G., "Corrosion Engineering", McGraw-Hill, 2005
4. I. H. Khan, Corrosion Technology, Vol. 1 & 2, Institute of Chemical Engineering, Uni. of The Punjab, Lahore, Pakistan.

**MME-504      Production and Properties of Metals and Alloys      (3+0)**

Production, properties and applications of Iron-Carbon Alloys, Plain carbon steels, Low alloy steels, stainless steels, surgical steels, Tool steel, Cast Iron.

Production, properties and applications of Copper and Copper Alloys, Aluminium and aluminium alloys, Titanium and titanium alloys, Magnesium and Zinc alloys, Nickel and Cobalt alloys (Super Alloys)

Production, properties and applications of refractory metals and alloys

**Recommended Books**

1. Honeycombe, R. W. K., and Bhadeshia, H. K. D. H., “Steels, Microstructures and Properties”, Edward Arnold, 2005.
2. Polmear, L.J., “Light alloys- Metallurgy of the Light Metals”, 3rd ed., Arnold, 1999.
3. Christian, J. W., “Transformations in Metals and Alloys”, Pergamon Press, 1975
3. M. A. Benvenuto, Metals and Alloys, De gruyter, 2nd edition, 2016.

**1(b) M.Sc. in Metallurgical and Materials Engineering with Specialization in Nano and Advanced Materials**

**Core courses are the same as in 1(a)**

***Elective Courses***

**MME-516    Nanomaterials and Nanotechnology    (3+0)**

Emergence of Nanotechnology, Synthesis of nanomaterials (Bottom up and bottom down techniques), Physical Chemistry of Solid Surfaces: Surface Energy, Chemical Potential, Electrostatic Stabilization, Surface charge density, DLVO theory, Steric Stabilization, Surfaces and interfaces, Ceramic interfaces, super hydrophobic surfaces

Zero-Dimensional Nanostructures: Nanoparticles: Homogeneous Nucleation, Growth controlled by surface process, Synthesis of nanoparticles (metallic, semiconductor, oxide nanoparticles), sol-gel processing, Forced hydrolysis, Vapor phase reactions, Heterogeneous Nucleation, Kinetically Confined Synthesis, Synthesis inside micelles or using microemulsions, Aerosol synthesis, Growth termination, Spray pyrolysis, Template-based synthesis

One-Dimensional Nanostructures: Nanowires and Nanorods: Spontaneous Growth, Evaporation (dissolution)-condensation growth, Fundamentals of evaporation (dissolution)-condensation growth, Evaporation-condensation growth Dissolution-condensation, Fundamental aspects of VLS and SLS growth, VLS growth of various nanowires, Control of the size of nanowires

Overview of Nanomaterials: Quantum Dots, Nanowires nano-rods, Thin films and monolayers, Carbon-based nanomaterials: Carbon nanotubes, Graphene, Nanostructured carbon

Nanomaterials properties: Electrical, Magnetic and Optical properties, Deformation behavior, Fracture and creep of nanomaterials. Characterization of nanomaterials. Nano-biotechnology, Nano-mechanics and nano-tribology. Nanotechnology and its prospects for industry, Applications of nanostructures: Reinforcement in Ceramics, Drug delivery, Giant magneto-resistance, etc. Cells response to nanostructures.

**Recommended Books**

1. Nanoscale Science and Technology by Kelsall, Hamely & Geoghegan    Wiley (2005)
2. Nanostructures and Nanomaterials: Synthesis properties and applications by Cao, G., Wang, Y. 2<sup>nd</sup> ed. World Scientific, Singapore, (2011).
3. Handbook of nanotechnology by Bhushan, Springer, 2003

**MME-517 Energy Materials (3+0)**

Introduction, batteries and capacitors, ion transport, electrolytes, anodes and cathodes in batteries. Fossil Fuel energy sources, Solar radiations, Thermoelectric materials, solar cells, organic solar cells, Si solar cells, semiconductors for photovoltaics, Material in fuel cells. Wind energy, hydroelectric power, geothermal power. Hydrogen as a fuel and energy storage material, Nanotechnology for batteries and fuel cells, solid oxide fuel cells (anodes, cathodes electrolytes, interconnects, seals), catalysis, noble metal catalysis, oxide catalysis, introduction to membranes, porous membranes, dense membranes

Reference Books

1. Fundamentals of Materials for Energy and Environmental Sustainability Edited by David Ginley and David Cahen, Cambridge University Press
2. Advanced Batteries, Materials Science Aspects Robert A Huggins, Springer
3. Fuel Cell Fundamentals Ryan O'Hare, Suk-Won Cha, Whitney Colella, and Fritz Prinz, Wiley

**MME-518                      High Temperature Materials                      (3+0)**

Introduction, applications and requirements of materials to be used in high temperature. Corrosion at elevated temperatures. Design of Alloys for High Temperature Services, Strengthening Mechanisms, Creep and Stress Rupture, Fatigue and Thermal Fatigue.

Super-alloys: their processing, high temperature mechanical properties, corrosion behaviour, micro-structural degradation behaviour of super alloy, Ni, Ti, Co and Fe base super alloys, refractory metals and alloys, oxidation resistant coatings and thermal barrier coatings

High temperature polymers, carbon-carbon composites, carbon-matrix composites for refractory applications.

Application of High Temperature Materials in automotive and aerospace industry.

**Recommended Books**

1. Yoseph Bar-cohen, High Temperature materials and mechanisms, Taylor & Francis Group, 2014
2. Meetham, G.W., Van de Voorde, M.H. Materials for High Temperature Engineering Applications, Springer, 2000.
3. John B Hudson, "Surface Engineering: An Introduction", Butterworth Heinemann, 2000
4. Bose "High Temperature Coatings" Butterworth Heinemann 2007
5. Lang E., "Coatings for High Temperature Applications", Applied Science, 2000

**MME-519      Biomaterials                      (3+0)**

Introduction and classification, biocompatibility and bioactivity, organic materials processing and synthesis, surfactants, hydroxyapatite (HA) coatings, Total Hip Joint and Knee Joint Replacement implants, materials selection for implants and prostheses, dental materials, enamels, hard and soft tissue regeneration, Transplants, Tribology of human joints Ti alloys and shape memory alloys Bio and Tissue Engineering.

Introduction and applications of biomaterials, Biocompatibility, biomimetic materials and tissue engineering, Body reaction and response to material implantation, Tissue response to material implantation, Blood response and hemocompatibility.

Metallic Biomaterials (Stainless steels, Co-Cr, Titanium alloys, gold and noble metal alloys, NiTi, and Shape Memory Alloys), Bio-corrosion, Bioceramics (Hydroxyapatites), Bioinert, biodegradable and bioactive ceramics, Hard and soft tissues, Collagen and elastin, Tissue-derived biomaterials, Synthetic polymers, Composite biomaterials, Prostheses, Biocompatibility tests.

biocoatings and substrate materials, Biocompatible and bioactive coatings, Antibacterial coatings, Types of biological tests for bioactive coatings.

**Recommended Books**

1. Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons,  
Biomaterials Science, 3rd Edition: An Introduction to Materials in Medicine,  
Academic Press, 2012
2. Jeffrey O. Hollinger, An Introduction to Biomaterials, 2nd Edition (Biomedical  
Engineering, CRC Press 2011
3. M. Niinomi, T. Narushima, M. Nakai, Advances in Metallic Biomaterials, Springer, 2014
4. Cuie Wen, Surface Coating and Modification of Metallic Biomaterials, Woodhead  
Publishing, 2015.
5. Wolfgang Knoll, Handbook of Biofunctional Surfaces, Pan Stanford, 2013

**MME-520    Advanced Materials    (3+0)**

Crystal structures and defects in functional materials, Heat conduction mechanisms and thermal expansion. Electrical conduction, insulation, dielectric, optical and magnetic properties of various materials.

Application fields of porous functional materials, Functional surface properties. Self-cleaning, easy-to-clean surfaces, photo catalysis, antibacterial surfaces. Biologically inert or active materials, bio ceramics.

Shape Memory Alloys, Bulk Metallic glasses, Energy storage materials, Self-healing materials, Functional coatings for metals, polymers and glasses: hydrophobic and hydrophilic surfaces, anti-ice coating, anti-microbial coatings, air curable coatings  
transparent conductive coating, barrier coatings, integrated functional coatings

**Recommended Books**

1. Shi, Donglu, Functional Thin Films and Functional Materials, Springer, 2003
2. Seeber, Renato, Terzi, Functional Materials in Amperometric Sensing, Springer, 2014
3. Tiwari, L. Uzun, Advanced Functional Materials, Wiley, 2015
4. Martin Scholz, Biofunctional Surface Engineering, Pan Stanford Publishing, 2014
5. Wolfgang Knoll, Handbook of Biofunctional Surfaces, Pan Stanford, 2013

**MME-521      Nanostructured Materials and Devices      (3+0)**

Design of nanoscale, materials, nanostructure and physical properties, modeling and simulation, nano-device, fabrication techniques, nanoparticles, nanowires, nanorods and thin film technology, sensors and devices, MEMS and NEMS, field emission devices, Manufacturing of nanoscale materials, fabrication tools for nanostructures and nanodevices, nanofabrication, surface science and properties, multi-scale modeling of stress localization and fracture of nanocrystalline materials, nanoscale intelligent and smart materials and structures.

**Recommended Books**

1. Shi, Donglu, Functional Thin Films and Functional Materials, Springer, 2003
2. Seeber, Renato, Terzi, Functional Materials in Amperometric Sensing, Springer, 2014
3. Tiwari, L. Uzun, Advanced Functional Materials, Wiley, 2015
4. Martin Scholz, Biofunctional Surface Engineering, Pan Stanford Publishing, 2014
5. Wolfgang Knoll, Handbook of Biofunctional Surfaces, Pan Stanford, 2013

**MME-522 Carbon Nanomaterials (3+0)**

Fullerenes and their derivatives, structure and properties, molecular and crystal structures, chemistry of carbon nanotubes, C60, SWT and MWT, carbon clusters, synthetic and nanocrystalline diamond, structure, properties and applications, nanobelts, graphite whiskers, cones and polyhedral crystals, nanocrystalline diamond, carbide derived carbon, polymeric nanocomposites, nanotextured carbon for energy storage.

**Recommended Books**

1. T.D. Burchell, Carbon Materials for Advanced Technologies - 1st Edition – Elsevier, 2009
2. A. Tiwari, Advanced Carbon Materials and Technology, Wiley, 2014
3. Tiwari, L. Uzun, Advanced Functional Materials, Wiley, 2015

**MME-523      Thin Film Technology      (3+0)**

Thin film growth techniques, PVD, CVD, MBE, magnetron CVD process, diamond like (DLC) coatings, tribological and hard coatings for tools, and engineering applications, functional coatings for electronic and magnetic materials, applications, evaporation and sputtering techniques, atomic layer deposition (ALD), advanced surface characterization techniques.

**Recommended Books**

1. Shi, Donglu, Functional Thin Films and Functional Materials, Springer, 2003
2. Seeber, Renato, Terzi, Functional Materials in Amperometric Sensing, Springer, 2014
3. Tiwari, L. Uzun, Advanced Functional Materials, Wiley, 2015
4. Donald Mattox, Handbook of Physical Vapour Deposition (PVD) Processing, 2nd Edition, William Andrew 2010
5. John B Hudson, "Surface Engineering: An Introduction", Butterworth Heinemann, 2000

**MME-524      Advanced Powder Processing      (3+0)**

Overview of powder metallurgical technology, Mechanochemical synthesis of nanocrystalline metal powders, Sintering mechanism and advancements, Advanced powder metallurgy steel alloys, Powder metallurgy tool steels, Powder metallurgy of titanium alloys, Additive layer manufacturing and powder injection moulding, Metal-based composite powders, Porous metals production by P/M: foams and sponges, slip casting of metal powders, Microwave sintering of metal powders, plasma sintering, Joining processes for powder metallurgy parts, Non-destructive evaluation of powder metallurgy parts, Real-time on-line powder metallurgy parts inspection, Fatigue and fracture of powder metallurgy steels, Automotive applications of powder metallurgy, Innovative powder metallurgy products, Applications of powder metallurgy in biomaterials, Latest research trends in powder metallurgy.

**Recommended Books**

1. I Chang, Y Zhao. Advances in Powder Metallurgy, Woodhead Publishing, 2013
2. Katsuyoshi Kondoh, POWDER METALLURGY, Published by InTech, 2012.
3. Hirschhorn, S Joel. Advanced Experimental Techniques in Powder metallurgy
4. POWDER METALLURGY: SCIENCE, TECHNOLOGY AND APPLICATIONS, P. C. ANGELO, R. SUBRAMANIAN, PHI Learning Pvt. Ltd., 2008.

**MME-525 Nanocomposites (3+0)**

Ceramic/Metal Nanocomposite Systems. Preparation technologies: mechanical alloying, sol-gel synthesis, melt spraying. Structures: particles, thin films, wires, porous systems. Applications: electrical, magnetic, optical.

Nanocomposites based on polymer matrix, polymer / polymer, ceramic / polymer, metal / polymer, carbon nanotube / polymer. Preparation technologies: solid mixture, solutions mixing, in-situ polymerization, polymer coatings, other coatings. Applications: mechanical, electrical, optical.

Natural nanocomposites: Nanocomposites synthesized biologically; Nanocomposites synthesized by mimicking natural processes; Packaging proteins.

Nanocomposite materials modeling: current issues. Multiscale modeling. Multi-physics modeling.

**Recommended Books**

1. Ajayan P.M. (ed): *Nanocomposite Science and Technology*, Wiley Verlag GmbH, Weinheim, 2003, ISBN 3-527-30359-6.

2. A.D. Pomogailo and V.N. Kestelman, *Metallopolymer Nanocomposites*, Springer-Verlag Berlin Heidelberg 2005, ISSN 0933-033x.

3. Strosio M.A., Dutta M. (ed): *Biological nanostructures and applications of nanostructures in biology*.

*Electrical, mechanical and optical properties*, Kluwer Academic, 2004, ISBN 0-306-48627-X.

***General Elective Courses for both streams 1(a) and 1(b):***

**MME-526      Production Management and Quality Control      (3+0)**

Principles of Organization charts based on line-staff-committee aspects. Social psychology. Personnel and legal aspects of labour relations. Unions. Factory Laws. Health and safety in industry. Costs, depreciation, yields and Scrap.

Financial controls. Investment assessment. Accounting. Interpretation of balance sheets. Stocks. Limited liability companies. Financial direction. Bank. Money market. Stock Exchange. Current economic problems. Introduction to principles of operational research and work study.

Selection and assessment of materials. Management statistics.

Introduction to Management Information Systems, People, Organizations, Systems and Management, Systems and Models, Management and Decision Making.

Information Technology Concepts: Hardware Fundamentals. Software Fundamentals. Database Management. Telecommunications. Transaction Processing and Management. Decision support system. Knowledge based system. Office Information systems.

Building Management Information Systems: Requirement Analysis, system design, system acquisition. Information and Maintenance. End user computing and development. M/s Management.

Information Resource Management. Selected issues in M/s Management.

**Recommended Books**

1. Lockyer, K. G., "Production Control in Practice", Pitman, 2007
2. Norman Gaither, "Production and Operation Management", Dryden Press, 2007
3. William Gavett Harcourt, "Production and Operation Management", Brace & World, 2006

**MME-527 Industrial Safety and occupational hazards (3+0)**

Introduction to occupational health and safety, definition and classification of accidents, job safety analysis, accident investigation, definitions of slip, trip and falls, walking and working surfaces, fall prevention and protection, Exposures to chemical, biological, and radiological hazards, Manual materials handling and lifting, Equipment-aided handling, Powered industrial trucks, Cranes, Materials storage, OSHA recordkeeping and reporting General requirements of PPE, Eye, head, hand, foot protection, First Aid, Fire and process safety (cause, prevention, response to fire, training for fire protection, emergency plans, emergency marking, plan for emergency), respiratory hazards, air monitoring, ventilation (control of airborne hazard), confined space standard, occupational noise exposure, temperature stress, electrical wiring methods, polarity, grounding, extension cords, plug-and-cord connected equipment, combustion and explosion, controlling ignition hazards, Hazardous agents (metals, gasses, corrosives, solvents, biocides, etc.), Toxicology – exposure and entry (Exposure routes, Local effects, Gastrointestinal absorption, Respiratory absorption, Skin absorption etc.), Ergonomic ailments and their causes (Anatomy basics, Cumulative trauma disorders, Hand-arm vibration syndrome, human factor problems), Identification and control of ergonomic stresses (Injuries and other indicators of ergonomic problems, Major risk factors: repetition, force, position, Other factors: vibration, cold, sharp edges, production pressure, environment), Ergonomically neutral positions, Ergonomic task analysis, Control of ergonomic stresses: administrative, engineering, personal protection, Tool and task design, Risk assessment and management, OSHA four point program, training and motivation, inspection programs.

**Recommended Books**

1. Thomas J. Anton, “Occupational Safety & Health Management”, 2nd ed, McGraw Hill, 2006
2. Daniel E. Della-Giustina, “Safety and Environmental Management”, 2001
3. Ronald Packman, “A Guide to Industrial Safety and Health” Longmans, 2007