

## **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.

### **Elective Courses**

#### **MME-505      Advance Ceramics      (3+0)**

Bonding in ceramics (Ionic and covalent bonding), Atomic structure of ceramics, Composite Crystal Structures (network formers, modifiers and intermediate oxides), Structure of Silicates, Lattice Parameters and Density, scope of ceramics materials, Classification of ceramic (conventional and advanced), Mechanical properties (strength, toughness, and microstructural design), Chemical Forces Effect on Physical Properties, Surface Energy,

Atomic defects, including intrinsic and extrinsic point defects, Kroger-Vink notation, defect reaction equilibria. Electrical properties including, dielectrics, piezoelectrics, ferroelectrics and Magnetic properties, Ferrimagnetic materials, Microstructure control and its effects on properties. Thermal properties including heat capacity, thermal conductivity, thermal expansion, creep, and thermal stresses, Thermal Diffusivity of Ceramics.

Application of ceramics in energy, bio, aerospace and defence applications

#### **Recommended Books:**

1. W. D Kingery, Introduction to ceramics, 2<sup>nd</sup> Edition, Wiley 1976.
2. M. W. Barsoum, Fundamentals of Ceramics, CRC Press, 2002.
3. D. W. Richerson The Magic of Ceramics, 2nd Ed., Wiley 2012
4. Advances in Ceramics - Characterization, Raw Materials, Processing, Properties, Degradation and Healing, C. Sikalidis, InTech 2011
5. F. H Norton, Elements of Ceramics, CBLS Publishers, 1991.
6. F. Singer, Industrial Ceramics, Springer 1963

**MME-506      Composite Materials                      (3+0)**

Natural Composites, classification, properties and comparison of properties to other conventional materials, Different types of reinforcements, Manufacturing processes of reinforcements/fibres, Characteristic features of fibres, Introduction to matrices and their types, Interfaces and their characterization, Macro and Micro Mechanics of Composites, Responses of polymer composites to different mechanical loading, Principles and features of different mechanical test methods, Processing of thermoplastic; injection moulding, compression moulding, glass mat-thermoplastic (GMT) - Processing of thermosetting; filament winding, pultrusion, unidirectional prepreg, autoclave processing, resin transfer moulding, sheet moulding compound (SMC), Metal matrix composite processing, Properties of MMCs, Application of MMCs, Multifilamentary Superconducting Composites, Processing and structure of glass-ceramics, ceramic matrix composites, Secondary Processing and Joining of Composite. Fatigue and Creep properties of Composites, Advanced / Industrial Application of Composite Materials.

**Recommended Books**

1. Ronald F. Gibson, "Principles of Composite Material Mechanics", 3rd ed, September 2011
2. Ever J. Barero, "Introduction to Composite Materials Design", 2nd ed, July 2010
3. Deborah D L Chung, "Composite Materials", Springer, 2003

**MME-507      Joining of Materials                      (3+0)**

Science and practice of materials joining processes. Defects in welded structures. Testing and evaluation of stresses and defect in welded structures. Welding Qualifications and Testing: welding procedure specification sheets (WPS), Procedure qualification records (PQR), Welding Defects, Inspection and testing of weldments (AWS, ASME, ASTM)

Weld design, welding codes and symbols. Fabrication of engineering components. Thermal cutting of engineering materials. Adhesive bonding. Application and analysis of welded structures. Discussion on relevant case studies. Welding Metallurgy. Mechanical Fastening, Friction Stir Welding, Joining of Polymers and Composites, Joining of Dissimilar Metals

**Recommended Books**

1. Easterling, K., "Introduction to the Physical Metallurgy of Welding", Butterworth-
2. Heinemann, 2000
3. Tiku, G. L., "Manual on Joining Processes by Welding, Brazing and Soldering" Minerva Press, 2003
4. Robert W. Messler, "Joining of Materials and Structures: From Pragmatic Process to Enabling Technology", Butterworth-Heinemann; 1st Edition, 2004.
5. Brian Smit, Welding Practice, Routledge, 2014
6. J. F. Lancaster, Metallurgy of Welding, Springer, 3rd Edition, 2012
7. Robert W. Messler, "Principles of Welding: Processes, Physics, Chemistry and Metallurgy", Wiley & Sons, 2015

**MME-508      Solidification Processes      (3+0)**

Overview of conventional casting practices, Properties of metals and alloys before and during solidification. Surface phenomenon, surface energy, surface tension, wetting angle. Wetting speed. Classification and influence of wetting.

The primary crystallization. Mechanisms of crystallization. Multiplication of nucleuses. Endogenous and exogenous crystallization. Undercooling and its components. Basic morphological types. Volume changes during cooling and solidification. Shrinking. Five mechanisms of feeding by Campbell. Refining and modification.

Rapid solidification processes (RSP) for control crystallization. Classification of high cooling rates. Undercooling and recalescence. Amorphous state. heat treatment, Application

Pressure solidification processes (PSP). primary crystallization, thermo-physical properties, cooling rate, primary structure of high external pressure. Practical use of the rheological behavior of the alloys, Case studies of selected castings.

**Recommended Books**

1. Chastain Stephen D, "Metal Casting," Chastain Publishing, 2003
2. Ulla Akerlind, Solidification and Crystallization processing in Metals and Alloys, 2008
3. Campbell. John, "Castings" Butterworth-Heinemann; 2nd Edition, 2003.
4. Peter belay, Foundry Technology, Butterworth-Heinemann; 2nd Edition, 2003.
5. Brooks. Nick, "Mould making and Casting" Crowood Press, 2005



**MME-509      Metal Working Processes      (3+0)**

Metal working Theory: Stress analysis of metal working processes. Slip-line field theory. Upper-band theory. Plastic flow in rolling, forging and extrusion.

Metal working processes: Factors influencing quality in hot flat rolling and their subsequent influences on cold strip production, calculation of rolling force, Rolling defects, Types of rolling mills

Open and closed die forging, Factor affecting the forging process, Calculation of forging force and capacity of forging press, Die design, Die materials and lubricants, Forging defects, Economics in forging process, Forging Equipment

Effects of tool profiles and lubrication in hot extrusion. Speed and temperature variables. Principles of hydrostatic extrusion. Impact and cold extrusion process; economic and metallurgical evaluation. Automatic rod drawing equipment. Wet and dry drawing of wire and tubes. Tool design and analysis of metal flow. Properties of drawn material. Redundant work in wire drawing. Selection of tool materials for close-die forging, factors affecting die shape.

Performance in shearing, bending, stretch-forming and deep drawing. Influence of material variables, tool forms and lubrication. The problem of analyzing complex asymmetric pressings. Experimental approach to the identification of critical factors. Quality Control of sheet materials. Recent developments in material working processes.

**Recommended Books**

1. Kalpakjian and Schmid, "Manufacturing Processes for Engineering Materials" Prentice Hall, 7th Edition 2014.
2. Mikell P. Groover, Introduction to Manufacturing Processes, Wiley 2011
3. Creese, R. C., "Introduction to Manufacturing Processes and Materials", Taylor and Francis, 1999
4. Hwaiyu Geng, "Manufacturing Engineering Handbook", McGraw-Hill, 2004
5. George Dieter, Mechanical Metallurgy SI Metric Edition, McGraw-Hill, 2000.

**MME-510 Fracture Mechanics and Failure Analysis (3+0)**

Linear elastic fracture mechanics, crack opening displacement (COD), stress intensity factor, J integral, elastic-plastic fracture mechanics, , plane stress and plane strain fracture toughness, real time fracture toughness, fracture re-inforcement mechanisms, Elastoplastic fracture mechanics, Griffith's theory, Fracture toughness, Ductile and Brittle fracture, Tensile fracture, Creep and Creep fracture, fatigue and Fatigue fracture, theory ductile to brittle transition, effect of temperature, micro-voids formation and ductile fracture, cleavage for brittle fracture, cleavage planes, Fractography, differentiation among different types of fracture surfaces Root cause analysis, Case studies of failed components.

**Recommended Books**

1. Anderson, Ted, Anderson, T. L., "Fracture Mechanics Fundamentals", 3rd Edition, Taylor & Francis Group, 2005.
2. Knott, J. F. and Withey, P., "Fracture Mechanics - Worked examples", IoM, Latest edition.
3. Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, Wiley 2012.

**MME-511 Coating Techniques and Surface Analysis (3+0)**

An overview of coating techniques and importance

Organic Coatings: Coating Functionality, Basic Components, Paints, Applying Paint Coatings, Plastic Linings, Temporary Preservatives

Inorganic (Nonmetallic) Coatings: Vitreous Enamels, Anodizing, Phosphatizing, Chromate Filming, Nitriding, Passive Films, Physical Vapor Deposition, Chemical Vapor deposition, Thermal Spraying

Metallic Coatings: Methods of Application, Electroplating, Specific Metal Coatings, Nickel Coatings, Zinc Coatings, Cadmium Coatings, Tin Coatings, Chromium-Plating, Electroless Plating, Hot-Dip Galvanizing, Cladding, Aluminizing, Metallizing.

Why Coatings Fail, Soluble Salts and Coating Failures, Economic Aspects of Coatings, Selection and Maintenance

Coating analysis and Characterization: Microstructural, mechanical, tribological, functional etc.

**Recommended Books**

1. Donald Mattox, Handbook of Physical Vapour Deposition (PVD) Processing, 2nd Edition, William Andrew 2010
2. John B Hudson, "Surface Engineering: An Introduction", Butterworth Heinemann, 2000
3. Bose "High Temperature Coatings" Butterworth Heinemann 2007
4. Lang E., "Coatings for High Temperature Applications", Applied Science, 2000

**MME-512      Polymeric Materials                      (3+0)**

Introduction and applications of polymeric materials, Mechanisms/methods of polymer formation  
Viscoelasticity of polymer melts. Viscosity dependence on temperature, pressure, structural parameters  
and test conditions. Recycling of polymers.

Advanced synthesis methods, hybrid polymers and inorganic nanomaterials, stimuli responsive  
polymers, biopolymers in materials synthesis, interfacial properties of polymer brushes,  
polyelectrolytes, polymer nanocomposites, and nanofabrication of biopolymers. Living  
polymerizations; controlled radical polymerizations, dendrimers and hyperbranched polymers;  
copolymers, degradation of polymers, chemical transformations of synthetic and natural polymers,  
polymers from renewable resources; self-healing polymeric materials.

Polymer Coatings: Design and formulation of waterborne, high-solids and powder coatings. Stimuli-  
responsive polymeric films and coatings, smart coatings and nano-coatings, design requirements and  
considerations, evaluation of polymer coatings

**Recommended Books**

1. Rose A. Ryntz, Philip V. Yaneff, Coatings of Polymers and Plastics, CRC Press, 2003.
2. Arthur A. Tracton, Coatings Materials and Surface Coatings, CRC Press, 2006.
3. Mark, James E, Physical Properties of Polymers Handbook, Springer 2007.

**MME-513                      Electronic, Magnetic and Optical Materials    (3+0)**

Classification and concept of Electrical and Electronic Materials, Conductivity and electrical resistivity of metals and alloys, Superconductivity, Formation of Single crystal of Silicon. Intrinsic and extrinsic semiconductors, Effect of doping, Effect of temperature on intrinsic semiconductor, Effect of temperature on the electrical conductivity of extrinsic semiconductors, Applications, Insulators and Dielectric properties, Electric resistance alloys, types of resistance alloys, thermostat metals, heating alloys

Photonic or Optical materials, Electromagnetic Spectrum, Refraction, Reflection, Absorption and Transmission, Selective absorption, Examples and use of Emission Phenomena, Design of a Fibre Optic System, Design of a Radiation Shield, Design of a Stealthy Aircraft

Classification of Magnetic Materials, Applications of Magnetic Materials, Desirable properties for Soft Magnetic Materials to be used for Electrical Engineering applications, Design/ Selection of magnetic Materials, Design/ Materials selection for a Solenoid, Desirable properties for Data Storage Material, Desirable properties for Hard Magnetic Materials, Single domain particles.

Soft and Hard Ferrites, Production route and their potential applications, Fe-Si Alloys, Metallic Glasses, Ni-Fe alloys, Alnico Alloys, Origin of Ferromagnetism in Rare Earth Transition Permanent Magnets, Production of Rare earth based magnets, Processing and physical metallurgy of SmCo type permanent magnets, Comparison of RFeB and SmCo Magnets, Applications, Design/Materials Selection for a High Temperature Magnet.

**Recommended Book**

1. Lee, Electronic, Magnetic and optical materials, 2016
- C. D. Graham, Introduction to magnetic materials, 2008
- Electronic Properties of Materials, R.E. Hummel, 4<sup>th</sup> Edition, Springer.
2. Supplemental text and reading: Principles of Electronic Materials and Devices, 3<sup>rd</sup> Edition, McGraw-Hill,

**MME-514 Phase Transformation in Materials (3+0)**

Phase transformations. Homogeneous and Heterogeneous solidification. Force-based and energy-based equilibrium geometry of the critical nucleus. Effect of solidification and microstructure on glass formation. TTT diagrams. Nucleation of precipitates from a supersaturated solid solution, Nonequilibrium transition phases, Coherent, semi-coherent, and incoherent interfaces and energetics. Heterogeneous nucleation of precipitates and effects of matrix microstructure. Spinodal decomposition of materials. Strain energy as a driving force for recrystallization. surface energy and grain coarsening; implication to nanostructures. Introduction to martensitic transformations.

Introduction to surfaces and interfaces. Estimation of surface energies for solids and liquids. Effect of particle size on chemical potential. Effect of crystallographic orientation on surface energy. Singular and vicinal surfaces. The Wulff theory. Twist and tilt grain boundaries, low-angle and high-angle boundaries.

Material transport by diffusion. Types of diffusion, Fick. 1<sup>st</sup> and 2<sup>nd</sup> law. Thin film and error function solutions. Sievert's Law. Role of temperature, crystal structure, atomic size ratios, grain boundary structure, melting point on rates of diffusion. Microstructural effects. Self-diffusion coefficients and the role of homologous temperature. Interdiffusion, the Kirkendall effect, Relationships between concentration gradients and chemical potential gradients. The formulation of diffusion in terms of chemical potential gradients.

**Recommended Books**

1. Mats Hillert, "Phase Equilibria, Phase Diagrams and Phase Transformation: Their Thermodynamic Basis", 2nd Edition, December 2007
2. L. Dossett and H. E. Boyer, "Practical Heat Treating: Second Edition", ASM International, 2006.
3. Harry Bhadeshia, Robert Honeycombe, "Steels: Microstructure and Properties", Butterworth-Heinemann; 3rd Edition, 2006.
4. Porter, D. A. Easterling K.E. and Mohamed Y. S., "Phase Transformations in Metals and Alloys", Chapman & Hall, 3rd Ed. 2009.
5. Essential Readings in Light Metals, 4 Volumes, John Wiley & Sons Inc. 2013
6. I. Polmear, M. Qian, Jian-Feng Nie, D. St. John "Light Alloys, From Traditional Alloys to Nanocrystals", 5th Ed. 2017

**MME-515 Nuclear Materials (3+0)**

Functional requirements of materials in a nuclear environment, reactor internals and vessel, piping, valves, Nuclear fuel materials, Coolants and control materials, moderators and reflectors, Cladding materials, Neutron radiation damage and crystalline defects, Property changes due to neutron irradiation, Advanced treatment of irradiation effects in materials: radiation damage mechanisms at microscopic level, Thermal stability of defects, Types of reactors, Structural mechanics of fuel assembly and reactor systems. Corrosion and materials degradation problems in the nuclear industry, Technological aspects and environment-sensitive damage (light water reactors and steam generators), Nuclear waste treatment: corrosion effects on storage and disposal, Advances in reactor systems.

**Recommended Books**

1. Hemsworth "Nuclear Materials" Nova science PUB inc. 2011
2. Materials Science and Technology, Volume 10, Nuclear Materials, Parts I & II, Vol. Editor: Frost, B. R. T, VCH, 1994.
3. The American Society of Mechanical Engineers, "Performance and Evaluation of Light Water Reactor Pressure Vessels", 1987

***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