

DEPARTMENT OF MATERIALS ENGINEERING

Course Outline

MM-103: WORKSHOP PRACTICE

Importance and objectives of workshop: Practice, Safety norms, hazard Prevention, Personal Protective equipment (PPE), First aid and emergency Procedures. Tools: files, hammers, chisels, hacksaws, surface plates, etc. Operations: marking, filing, sawing, drilling, tapping. Assembly of metal parts using nuts and bolts. Introduction to Welding Processes. Arc welding (Manual Metal Arc). Gas welding (Oxy- Acetylene). Welding symbols and safety Practices. Hands-on: Butt joint, lap joint, T-joint. Lathe machine parts and operations: turning, facing, threading, knurling. Milling machine basics: up milling, down milling. Introduction to CNC machines (optional or advanced module). Introduction to Casting Processes. Pattern making and types of patterns. Moulding sand Types and Properties. Sand casting demonstration. Sheet metal tools: snips, stakes, mallets. Operations: shearing, bending, folding, riveting. Simple Projects: tray, funnel, toolbox

MM-104: ENGINEERING DRAWING AND COMPUTER GRAPHICS

Engineering Drawing: Drawing equipment and the use of instruments; basic drafting techniques and standards; freehand sketching of machine and engine components; geometrical curves, including plane curves: cycloid, hypocycloid, and the involutes. Intersections and development of surfaces of geometrical bodies such as Prisms, pyramids, cylinders and cones. Multiview Projection and drawing using first and third angle Projection methods, Types of pictorial views and drawing isometric views. Concept of working drawing of parts of machines and engines: size, description, dimensions, and specification; limit dimensioning and geometric tolerances; limits; fits and tolerances; conventional symbols. Computer Aided Graphics: Introduction, application of computers in drafting and designing, methods for creating drawing entities, common editing features, dimensioning with variable setting, Printing and plotting. The Software configuration of a graphics system; functions of a graphics package; constructing the geometry; Introduction to wire framing and solid modelling.

MM-105: INTRODUCTION TO ENGINEERING MATERIALS

Introduction to engineering materials, their scope and role in industrial development, classification of materials, importance of materials in engineering design, and material selection criteria (properties, cost, sustainability). Materials (structure-Processing-Properties-performance relationship), Atomic Structure and Bonding, Unit Cells, Crystal Structures, Crystal Systems, Miller indices of Directions and Planes, Linear and Planar Densities, Close-Packed Crystal Structures, Crystalline and Noncrystalline Materials: Single Crystals, Polycrystalline Materials, Anisotropy, determination of crystal structures. Defects in crystal structures (point defects, dislocations), Microscopic Techniques, Grain Size Determination, Mechanical Properties of Materials. Classification, Properties, and Processing of metals, ceramics, polymers and semiconductors. Material Processing (Manufacturing, casting, joining, heat treatment, additive manufacturing, Surface coatings, surface treatments). Corrosion and Degradation, Corrosion mechanisms and their prevention methods (coatings, cathodic protection), Degradation of materials (fatigue, creep, wear). Advanced Materials, Introduction to nanomaterials (carbon nanotubes, graphene), Biomaterials (implants), Smart materials (shape memory alloys, piezoelectric materials). Material Testing and Characterization, Mechanical testing (tensile testing, hardness testing). Sustainability and Recycling of Materials, Sustainable materials (recycled materials, bioplastics), recycling of materials (metals, polymers, ceramics), Environmental impact of materials. Laboratory activities.

MM-213: **MATERIALS THERMODYNAMICS**

Introduction to Materials Thermodynamics, the concept of system and surroundings, extensive and intensive Properties. First Law of Thermodynamics, concept of Enthalpy, calculation of heat of reactions, concept of heat capacity and its variation with temperature, Kirchoff's equation and its applications in calculating heat of reaction at high temperatures. The concepts of entropy are the second law of thermodynamics, reversible and spontaneous Processes, and the third law of thermodynamics, which is the calculation of the entropy of elements and reactions at various temperatures. Free energy, and the concept of driving force behind a chemical or physical reaction, Equilibrium constant, Le-Chatelier's Principle, Factors affecting the equilibrium position, Relationship of equilibrium constant with free energy, Calculations of equilibrium partial Pressures. Ellingham diagrams and their application to commercially important reactions. Behavior of solutions, concept of activity, ideal and non-ideal solutions, Raoult's and Henry's Law, Free energy of mixing, Gibbs Phase Rule, Clausius Clapeyron Equation, Concept of diffusion, Phase diagrams. Introduction to electrochemistry, Chemical and electrical driving force, EMF, determination of thermodynamic Properties from electrochemical data.

MM-210: **MECHANICS FOR ENGINEERING MATERIALS**

Review mechanics of materials. Deformation; strain; elastic stress-strain behavior of materials; Introduction to stress-strain diagram, working stresses, unit design, Introduction to elastic and nonlinear continua. Poisson's ratio; Determination of forces in frames; Simple bending theory; general case of bending; Shear force and bending moment diagrams; Relationship between loading, shear force and bending moment. Stress; Skew (antisymmetric) bending Direct, shear, hydrostatic and complementary shear stresses; Bar and strut or column; Theory of buckling instability, Thin ring, Elementary thermal stress and strain; General stress-method. Theory of elasticity, Analytical solution of elasticity problems brittle fracture. strain energy in tension and compression. Analysis of bi-axial stresses, principal planes, principal stress-strain, stresses in thin walled pressure vessels. Mohr's circles of bi-axial stress. Torsion of circular shafts, coiled helical spring, strain energy in shear and torsion of thin walled tubes, torsion of non- circular sections. Shear centre and shear flow for open sections, General case of plane stresses, principal stress in shear stresses due to combined bending and torsion plane strain.

MM-214: **MACHINE LEARNING IN MATERIALS ENGINEERING**

Introduction to machine learning in metallurgical and materials engineering: Materials discovery, Property Prediction, structure-Property relationships, materials design, and materials informatics Basic Math: Review of Linear Algebra, Statistics, and Probability Programming and Data Science Tool: Introduction to Python (scikit-learn, pytorch, Jupyter notebook), Materials Databases (Materials Project, Citrination) Linear Regression: Univariate, Multivariate, Polynomial Regressions Clustering data/classification: K-means/db-scan, classification trees/forests Computer vision: applying concepts from clustering data, training models and Evaluating results with validation methods(e.g. Cross-validation) Deep Neural Network: Basic architecture of neural networks, different types of neural networks, Retraining hyper parameter modification Excursion: Big data in Materials science, Inverse design of materials, DFT MIPotentials, Integrations of machine learning, simulations, and experiments.

MM-211: JOINING OF MATERIALS

Introduction to Joining Processes and Classification. Fusion Welding: Gas welding: Arc Welding Processes; Resistance Welding Processes; Special Welding Processes (Classification, Equipment, PPE, Testing and Defects). Solid State Joining: Brazing, Soldering, Adhesive Bonding, Friction stir welding, Laser, Plasma Classification, Equipment, PPE, Testing and Defect). Advanced Welding: hydrogen welding, plasma arc welding electro slag welding under water shielded metals, arc welding, vapor shielded metal arc welding. Resistance welding, resistance spot welding, multiple spot welding, flash and upset welding, percussion welding. Thermite welding, equipment techniques, Other Joining Processes: Mechanical Joints (Temporary and Permanent joints). Non-metallic Joining: Plastic welding, adhesive bonding, bonding materials, inspection and testing of weldment Cold welding, adhesive bonding, diffusion bonding, Joining of Polymers, Joining of Ceramics (Classification, Equipment, PPE)

MM-212: ENGINEERING CERAMICS AND GLASSES

Classification and types of ceramics and glasses; comparison between traditional and advanced ceramics; structure and bonding in ceramics – coordination number, interstitial sites, and types of crystal structures including silica, silicates, mullite, spinels, alumina, and zirconia; ceramic defects – point defects, defect reactions, Kroger-Vink notation; structure and formation of glasses – nature of bonding rules, glass-forming systems, vitrification, devitrification, and glass-ceramics; Processing and shaping techniques – powder Preparation, uniaxial and isostatic Pressing, injection molding, slip casting, tape casting, drying, and binder removal; sintering mechanisms and densification in ceramics and glasses; mechanical, thermal, and optical Properties of ceramics and glasses; oxide ceramics such as alumina and zirconia, and non-oxide ceramics including silicon carbide and silicon nitride; advanced applications of ceramics in high-temperature and structural environments; functional ceramics – ferroelectric, piezoelectric, and electrochemical ceramics; introduction to smart ceramics and nanoceramics; bio-ceramics for medical applications; glass and ceramic materials for energy and environmental technologies such as solid oxide fuel cells, thermoelectric devices; overview of ceramic and glass characterization techniques – XRD, SEM, thermal analysis, and mechanical testing.

MM-312: POLYMERIC MATERIALS

Polymer raw materials and synthesis of common polymers (such as PE, PP, PVC, PET, PS), Polymer chemistry, polymerisation, co-polymerisation, vulcanisation, kinetics of polymerisation. Polymer blending and compounding. Polymer structure, Properties (mechanical, thermal, chemical) and applications of thermoplastic and thermosetting polymers, elastomers and rubber, additives, adhesives and fillers. Mechanism of polymer deformation. Thermal transition in polymers. Polymer crystallinity, Liquid crystal polymers. Polymer Processing: Injection molding, Blow Molding, Compression Molding, Film Insert Molding, Gas Assist Molding, Rotational Molding, Structural Foam Molding, Thermoforming, extrusion, spinning, etc. Elastomeric Materials, types of elastomers, Processing of elastomers, coloring of elastomers, application of elastomers in tires, seals, gaskets, sports, etc. Polymer testing and characterization: DSC, TGA, UTM, DMA, Shore hardness, etc. Application of different polymers such as PE, PP, PS, PET, PMMA, ABS, Polyamides, Polyester, etc. in domestic and commercial use. Polymer paints and adhesives. Polymers in packaging. Polymeric foams. Advanced polymers (conducting, smart and bio degradable polymers). Degradation of polymers. Environmental considerations.

MM-314: **COMPOSITE MATERIALS**

Classification of reinforcements, their mechanical Properties and functions; ceramics, glass, carbon, boron, silicon carbide, metal, aramid. Forms of reinforcements; particulate, fiber filaments, whiskers, flakes. Pre-fabricated forms – Preforms, prepegs, fabrics, honeycomb and other core materials. Type of matrix, its mechanical Properties and functions – polymers (thermosets and thermoplastics), metals, ceramics, glass and carbon. Basic Principles in the design of composites and selection of matrix and reinforcement. Bonding mechanisms Anisotropic Behaviour and relationship between structure-mechanical Properties. Mechanical testing; tensile, compressive, Intra-laminar shear, Inter-laminar shear and fracture. Polymer Matrix Composites: Types of thermoset and thermoplastic resins. Principles in the selection of the matrix and the reinforcements. Process selection criteria. Mould and tool making. Basic manufacturing steps: impregnation, lay-up, consolidation and solidification. Manufacturing Processes for polymer composites: lay-up, compression moulding, extrusion, injection molding, sheet forming, pultrusion, hot Press & autoclave techniques and filament winding. Applications: industrial, automotive, marine and aerospace. Metal and ceramic matrix composites; wettability of reinforcement to matrix and bonding, methods of manufacturing reinforcements with intermediate wetting layer. Manufacturing Processes for metal matrix composites: casting methods; gravity & low Pressure die, investment, squeeze, spray forming, compressions molding and thixo-moulding. Manufacturing Processes for ceramic matrix composites: reaction sintering, electro-deposition, spray forming, infiltration. Applications; industrial, automotive and aerospace.

MM-315: **INSTRUMENTATION AND CONTROL**

Basic Concepts about instrumentation and Process control. Introduction to instrumentation as a key element in modern industrial systems. Overview of the importance of accurate measurement and control in maintaining efficiency, quality, and safety in processes. Fundamental concepts of process variables such as pressure, temperature, level, and flow. Introduction to control systems, feedback loops, and the role of sensors and actuators. Pressure Measurement: Pressure units, Manometers, Diaphragms, Bellows, Bourden Tubes, Secondary transducers (strain gauge and LVDT). Temperature Measurement: Introduction and units. Liquid Expansion Thermometers (Mercury in Glass, Liquid in glass), Bimetallic strip Thermometers, Pressure-Spring thermometers, Resistance Temperature Detectors thermistors, Thermocouples. Pyrometers. Level Measurement: Differential Pressure, Displacer, Bubbler, Capacitance, Conductance, Ultrasonic, Flow Measurement: Head type flow meters (Orifice plate, Venturi tube, pilot tube) Rotameter, Anemometers, Electromagnetic flow meters, Mechanical Meter (turbine type), Ultrasonic type flowmeter. Weight, force, stress, and strain measurement. Introduction to Process control: Process Control, Definitions of the Elements in a Control Loop, Units and Standards, Instrument Parameters, Control types.

MM-316: **MATERIALS CHARACTERIZATION & ANALYTICAL TECHNIQUES**

Introduction to characterization techniques and their application in Materials science and Engineering. Production and absorption of X-rays; use of filters; X-ray diffraction and Bragg's law; structure factor calculations; diffraction methods; rotating-crystal method. XRD spectrum and its Indexing; Precise lattice parameter determination; Particle size and micro/macro strains calculations. Chemical analysis by X-ray fluorescence. Scanning electron microscope (SEM); construction and working Principle; interaction of electrons with matter; modes of operation; image formation of plane and fractured surfaces. Energy Dispersive X-rays and wavelength dispersive X-rays systems; Electron diffraction and basics of transmission

electron microscopy (TEM); Image formation; resolving power and magnification; depth of focus; elementary treatment of image contrasts; important lens defects and their correction. Introduction to Scanning Tunneling microscope and its various types e.g. Atomic force microscopy; Piezo-force microscopy; Magnetic force microscopy etc. Introduction to Raman spectroscopy and its use in materials science. Spectroscopic techniques, spark emission spectroscopy, absorption spectroscopy etc. Thermal analysis of materials. Fourier Transform Infrared Spectroscopy, UV Vis Spectroscopy, X-ray photoelectron spectroscopy, cyclic voltammetry and electrochemical techniques.

MM-313: ELECTRONIC, MAGNETIC AND OPTICAL MATERIALS

Electrical and electronic materials are broadly classified based on their electrical conductivity into three primary categories: conductors, semiconductors, and insulators. Each type has distinct characteristics that determine its suitability for various applications in electronic devices and electrical systems. Classification and concept of Electrical and Electronic Materials. Metallic materials and their electrical Properties. Semiconductor materials and their electrical Properties. Semiconductor devices. Ceramic materials used in electronic applications. Magnetic materials and their classification. Magnetization curve, hysteresis loop. Types of magnetic behavior. Ferromagnetic domains. Experimental evidence for domains. Domain wall motion. Hindrances to wall motion. Soft Magnetic Materials: Desirable Properties for Soft Magnetic Materials. Potential applications of soft magnetic materials. Hard Magnetic Materials: Properties of Hard Magnetic Materials. Origin of Ferromagnetism in Rare Earth-based permanent magnets. Potential applications of permanent magnets. Different types of optical materials, Characteristics of optical materials, and applications.

MM-311: COMPUTATIONAL MATERIALS SCIENCE

Introduction to Computational Materials Science: Basic concepts of atoms and molecules. Types of atomic structures in metals and alloys (crystal lattices). Visualizing atomic structures using simple software (like Jmol or online tools). Overview of computational methods in materials science. Basic linear algebra, numerical methods, and statistical analysis relevant to material simulations. Modeling and Simulation of Material's Behavior/Properties: Molecular dynamics simulations, Density functional theory (DFT) and calculations using Monte Carlo simulations, Finite Element Analysis (FEA). Stress-strain behavior in materials: elasticity, plasticity, and fracture. Computational techniques for studying phase transformations in metallurgical Processes, Phase diagram calculations and phase transformation kinetics, Applications of computational methods in Predicting phase changes. Hands-on Projects and Case Studies: Simulation Projects using software tools e.g. Python/MATLAB, Solid works/ Materials Studio/ COMSOL/ ABAQUS/ANSYS, LAMMPS, Factsage, and others. Case studies on materials design and Process optimization through computational methods.

MM-418: PHASE TRANSFORMATIONS & KINETICS

Phase transformation in materials. Equilibrium transformations; first order & second order, Order-disorder transitions, transformations in complex structures, Driving force for phase transformation, Free energy changes during phase transformation, Concept of Gibbs's free energy, Volume free energy, & strain free energy Critical radius. Liquid-solid transformation, Solidification, Homogeneous nucleation; surfaces & interfaces; heterogeneous nucleation; polymer crystallization; nucleation rate; planar vs. dendritic interface growth; Gibbs-Thomson effect; dendrite velocity; alloy solidification; zone-refining; constitutional supercooling; solid- solid phase transformation; Nucleation & growth, homogeneous & heterogeneous

nucleation, nucleation on crystalline defects & on grain boundaries. spinodal decomposition, Transformation in the Solid-State Precipitation reactions, GP zones, Intermediate & stable precipitate, Coherency strain, Diffusion-controlled transformations. Interfacial energy- controlled transformations, e.g., transformations far from equilibrium conditions. Nano-scale particles. Diffusion less transformations. Ordered & disordered transformation, Recovery, crystallization & grain growth. Phase transformations in non-metallic materials & its effect on mechanical & physical properties. Transformations in glasses & organic materials.

MM-419: **QUALITY & PROJECT MANAGEMENT**

Introduction to Quality and project Management, Quality management principles. Quality management systems (ISO 9001), Total Quality Management (TQM), Quality Tools and Techniques, Project Management Fundamentals, importance and their concepts. Project Proposal development. Project Feasibility. Project Selection Criteria. Project Contract & Procurement Management. Project management life cycle, Project management knowledge areas (PMBOK), Project Planning and Scheduling, Project Execution and Monitoring and execution strategies, Earned Value Management (EVM). Project Costing & Estimation. Project HRM & Communication Management. Project Risk Management. Computer Application in Project Management. Project Quality Management, Quality planning and assurance, Quality control and improvement, Agile Project Management and Agile principles and methodologies such as Scrum framework and Kanban. Project Closure & Project Evaluation and Termination.

MM-423: **HEALTH, SAFETY & ENVIRONMENT**

Introduction, overview and importance of HSE, HSE regulations and standards, Roles and responsibilities, Occupational Health, Workplace hazards (chemical, physical, biological, Health risk assessment, Occupational health standards, Safety Management, Safety policies and procedures, Risk assessment and mitigation, Incident investigation and reporting, Environmental Management and their regulations and standards, Environmental impact assessment, Waste management and pollution control, Hazard Identification and Risk Assessment and their methodologies and mitigation strategies, Emergency Response and Planning, Fire safety and prevention, first aid and medical emergencies, HSE Regulations and Standards, Overview of relevant regulations (OSHA, EPA), Compliance requirements, Auditing and inspection, Environmental sustainability practices. An in-depth exploration of national and international HSE regulations, frameworks, and best practices. Overview of major regulatory bodies such as OSHA (Occupational Safety and Health Administration), EPA (Environmental Protection Agency), and ILO (International Labour Organization). Discussion of key legislation and guidelines that govern workplace safety and environmental compliance. Standards such as (Occupational Health and Safety), (Environmental Management), and sector-specific protocols are introduction

MM-424: **QUANTUM MATERIALS**

Quantum materials are systems in which quantum mechanical effects such as entanglement, superposition, and quantum coherence manifest macroscopically. Introduction & Overview of Quantum Materials (Definition and classification (topological materials, superconductors, quantum magnets)), Key properties (electron behavior, band structures), Fundamental Quantum Mechanics for Materials, Basic principles (wave-particle duality, Schrödinger equation, Blochs theorem), Quantum states and band theory, Density functional theory (DFT), Superconductivity (BCS theory, Cooper pairs, Meissner effect, High-temperature superconductors),

Topological Materials (Topological insulators and semimetals, Edge states and surface vs. bulk conductivity), Experimental Techniques (X-ray diffraction, ARPES, and STM in quantum materials), Applications (Quantum computing, spintronics, and quantum sensors), Emerging Quantum Materials such as Topological, spin liquids and 2D materials (graphene, TMDs). Topological Materials: Materials exhibiting robust edge or surface states protected by topological invariants. Superconductors: Materials that exhibit zero electrical resistance and expulsion of magnetic fields below a critical temperature.

MM-425: **ENERGY HARVESTING MATERIALS: ORGANIC & INORGANIC**

Covers the growing global demand for sustainable, off-grid energy sources. Emphasises the role of energy harvesting in powering remote sensors, medical implants, portable electronics, and IoT devices without the need for conventional batteries. Highlights the potential to reduce environmental impact and support self-sustaining, maintenance-free systems. Introduction, overview and importance of energy harvesting, Types of energy harvesting materials, Organic Energy Harvesting Materials, Organic photovoltaics (OPVs), Organic thermoelectric materials, Organic piezoelectric materials, Inorganic Energy Harvesting Materials, Inorganic photovoltaics (solar cells), Inorganic thermoelectric materials and Inorganic piezoelectric materials, Energy Harvesting Mechanisms, Photovoltaic, Thermoelectric and. Piezoelectric effects, Flexible and wearable energy harvesting, Energy storage materials and Hybrid energy harvesting systems, Applications of Energy Harvesting Materials such as Solar energy, Waste heat, Mechanical energy and Self-powered devices, Future challenges, Directions and Challenges and limitations

MM-426: **MATERIALS FOR BATTERY APPLICATIONS**

Introduction to Energy Storage: Importance, classification, applications (grid, EVs, consumer electronics), Fundamentals of Electrochemistry: Redox reactions, electrochemical cells, potentials, Nernst equation, Conventional Batteries I – Lead-Acid Batteries: Construction, working, advantages, limitations, Conventional Batteries II – Nickel-based Batteries (NiCd, NiMH): Chemistry, performance, issues, Lithium-Ion Batteries – Non-Aqueous Systems: Working principle, components, intercalation materials, Sodium-Ion and Aqueous Batteries: Recent trends, advantages, comparison with Li-ion, Solid-State and Polymer Batteries: Solid electrolytes, safety benefits, challenges, Metal-Air Batteries: Zn-air, Li-air, chemistry, design considerations, Battery Assembly Techniques: Coin cell fabrication, pouch/prismatic formats, safety protocols, Battery Testing and Characterization: Charge/discharge, cyclic voltammetry, impedance, capacity fade, Battery Management Systems (BMS): Components, SOC estimation, thermal management, balancing, Hydrogen Generation Techniques: Electrolysis, photoelectrochemical methods, reforming, Hydrogen Storage Technologies: Compressed gas, metal hydrides, cryogenic systems, Fuel Cells: PEMFC, SOFC, components, working, materials.

MM-427: **ADVANCED RECYCLING TECHNIQUES**

Concepts and importance of recycling and reusing materials in the context of environmental sustainability, resource conservation, and circular economy. Overview of material lifecycle and end-of-life challenges. The role of recycling in reducing raw material extraction, energy consumption, and landfill dependency. Policy frameworks and global initiatives encouraging recycling efforts (e.g., EU Green Deal, Extended Producer Responsibility, Zero Waste targets). Introduction, market analysis, environmental impact of recycling, Toxic materials and heavy metals and their toxicity mechanisms, Reusing of toxic materials. Wet and dry recycling

processes. Recycling and reusing of (i) glass and ceramics, (ii) polymer and plastics, (iii) polymer-based composite, (iv) metals and alloys, (v) electronics waste, (vi) paper, (vii) construction materials. Recycling and reusing of aircraft and ship materials. Environmental impacts of e-waste through treatment processes, Recycling of e-waste, Mechanical, Chemical, electrochemical and thermal recycling techniques, Recycling of nanomaterials, Landfill reclamation, Safety concerns in recycling, Health and safety risks in recycling plants, Application of nanotechnology in recycling, AI technologies for enhancing recycling.

MM-428: **ADDITIVE MANUFACTURING OF MATERIALS**

Additive Manufacturing processes create three-dimensional objects by building them layer by layer from digital models. Subtractive manufacturing, which removes material from a solid block, AM adds material only where needed, minimising waste. 3D printing, rapid prototyping, or digital fabrication, depending on context and application. Introduction to Additive Manufacturing, Overview, History, evolution, benefits and limitations of AM, Conventional methods vs AM technologies, AM Technologies such as Powder Bed Fusion (PBF), Directed Energy Deposition (DED), Material Extrusion (ME), Vat Photopolymerization (VP) and Sheet Lamination (SL) and its type. Materials for AM, Metals (Ti, Al, steel), Polymers (thermoplastics, thermosets), Ceramics, Composites and Biomaterials. Design for AM, AM Process Parameters and Control (temperature, speed, power), Process monitoring, control and assurance, Post-Processing and Finishing, Applications of AM, Future Directions, Challenges and limitations and Case studies

MM-429: **FUNCTIONAL MATERIALS**

Introduction to functional materials and their classifications: magnetic, optical, piezoelectric, thermoelectric, and shape memory materials. Fundamentals of magnetism, ferro-, para-, and anti-ferromagnetism and their applications in sensors and data storage. Basic principles of piezoelectricity and ferroelectricity with emphasis on perovskite structures and functional devices. Thermoelectric effects, including Seebeck and Peltier phenomena, and the concept of figure of merit (ZT). Overview of shape memory alloys and their role in actuation and smart systems. Relationship between crystal structure and functional properties, with emphasis on electrical and thermal conduction mechanisms involving phonons. Study of material properties: electrical, thermal, magnetic, optical, and photovoltaic. Surface and interface properties, nanostructure growth, photocatalysis, antibacterial and self-cleaning surfaces, and bio ceramics. Introduction to synthesis methods of common functional materials and discussion of their applications in electronics, energy devices, and other advanced technologies.

MM-430: **MECHANICAL BEHAVIOR OF MATERIALS**

Introduction and review of the structure of materials and crystalline imperfections. Elasticity (review of stress and strain concepts, Hooke's law, Elastic strain energy); Plasticity (Analysis of Stress-strain behavior, Yielding criteria of Metals and Hardness); Notches (Stress concentration factor, Neuber's rule, Tensile testing of notched specimens). Theoretical cohesive strength and Griffith criteria; Plastic deformation and role of Dislocations; types of dislocations; Slip systems; Critical resolved shear stress; Taylor factor; Dislocation interaction; Thermally activated processes; Intersection of dislocations. Ductile-brittle transition. Strengthening Mechanisms. Severe plastic deformation. Fracture behavior of metallic materials (ductile, brittle fractures); different types of embrittlement; Stress-corrosion cracking. Fatigue and creep deformation and fracture (Structural changes; theories and mechanisms of crack initiation and propagation; Materials'

selection). Mechanical behaviour of thin films and coatings; Mechanical behaviour of Polymers, Ceramics, glasses and composites; Weibull Modulus

MM-431: **FRACTURE MECHANICS AND FAILURE ANALYSIS**

Historical development and importance in engineering design. Limitations of classical strength-based approaches. Concept of stress concentration and failure beyond the yield point. Real-life case studies of structural failures Introduction & overview of the fracture mechanics, Fracture and its types, ductile, brittle (intergranular and trans granular), Plane stress and plane strain conditions, Griffith's and Orowan's theory of fracture. Linear elastic and elastoplastic fracture mechanics. Fracture Toughness Testing, stress intensity factor and its range. Paris Law. Determination of K_{1c}, Compact Tension, J-integral and Crack Opening Displacement (COD) methods. Tensile, Creep, Fatigue and environmental fractures. Stress corrosion cracking. Ductile to Brittle Transition Temperature and its determination. Fracture toughness testing of composites materials. Fracture toughness testing of reinforced/composite materials. Failure analysis procedures; Fractography and Case studies of fractured components; different types of mechanical/industrial failures (aerospace, automotive, biomedical); root cause analysis and remedial actions

MM-432: **POWDER METALLURGY**

Advantages and design limitations of powder metallurgy Powder particles sampling, dispersion & de-agglomeration; Sieve and microscopic analysis; sedimentation; laser light; particle size distributions; data presentation Characterization of powders: microstructure; particle shape; pycnometer; surface area test; internal structure and chemistry Production of powders: mechanical methods; electrolytic methods; Atomization techniques; chemical methods Powders modification and handling; mixing and blending; different lubricants and binders; Powders molding, shaping and compaction (cold and hot compacting methods physical characteristics of powder compacts, compaction defects). Sintering theory and practices, solid state and liquid phase sintering, modern sintering techniques, sintering atmospheres, thermodynamics of sintering. Inspection and quality control for P/M parts, the economics of P/M production, and new development in powder metallurgy processes

MM-433: **THIN FILMS AND PACKAGING MATERIALS**

Definition and importance of thin films in modern technology. Role of packaging materials in electronics, photonics, and MEMS. Overview of thin film and packaging applications: semiconductors, sensors, displays, photovoltaics, flexible electronics. Introduction to Thin Films, Thin Film Deposition Techniques, Thin Film Characterization Techniques, Packaging Materials Overview, Food and Pharmaceutical Packaging, Characterization of Packaging materials, Electronic and Semiconductor Packaging, Environmental Considerations and Sustainability, Regulatory and safety concerns (national and international standards). Spin coating, dip coating, spray pyrolysis. Sol-gel processing and inkjet printing. Applications and Emerging Trends such as Microelectronics, IoT, and mobile devices, Display technologies (OLED, MicroLED), Photovoltaics and flexible solar cells, Bio-integrated and implantable electronics, Sustainability in packaging: biodegradable, recyclable materials.

MM-434: **CRYSTALLOGRAPHY AND X-RAY DIFFRACTION**

Overview and scope of crystallography techniques used in materials engineering. Production of X-Rays, Absorption of X-Rays, Use of filters, X-Ray diffraction, Bragg's law, Structure factor calculations, X-ray scattering by atoms, crystal axes and reciprocal lattice, diffraction by small crystals, Diffraction methods, the powder method, Debye-Scherrer, the Laue back /reflection and rotating crystal method, the rotation method, scattering by non-crystalline form of matter, effect of temperature vibration on X-ray diffraction, x-ray studies of order-disorder, diffraction by imperfect crystals and perfect crystal theory, X-Ray diffractometer, Introduction to the crystal structure of materials. Symmetry, lattice directions and planes, crystal shapes, Crystal structure determination, Orientation of single crystal, Preferred orientation and Texture, Pole figures, Applications of X-Ray diffraction, Stereographic projections; Orientation of crystal concerning a reference, Rotation of crystal around an axis, Planes of a zone. Texture and stress analysis. Advanced X-Ray Diffraction Techniques, Small-angle X-ray scattering (SAXS), X-ray absorption spectroscopy (XAS). Practical examples of X-ray studies in materials engineering.

MM-421: **SURFACE ENGINEERING**

Tribology of surfaces: surface integrity; surface roughness and waviness; measurement of surface roughness and texture; friction and theories; types of wear and their mechanisms; lubrication and its regimes; applications of lubrication in wear. Mechanical surface treatment: Propelling abrasive media; blasting techniques; selection of abrasive media; different peening techniques. Surface finishing methods: selection and applications; tumbling; vibratory finishing; belt Sanding; wire brushing, buffing and electro-polishing. Chemical cleaning of surfaces: selection and applications; alkaline cleaning; solvent cleaning and vapor degreasing; molten salt bath cleaning; ultrasonic cleaning; acid cleaning; pickling and descaling. Coatings: Paints and organic coatings; powder coating; hot-dip coating; chemical conversion coatings; blackening; coloring of metals; electroplating, electrophoretic deposition; anodizing; electroless-plating; mechanical plating; Chemical vapor deposition (CVD) and Physical vapor deposition (PVD) techniques; Thermal and cold spraying methods; Sputtering; sol gel method. A brief overview of surface hardening methods. Cladding techniques; roll bonding; explosive welding; applications of cladding in nuclear, marine and other technological fields

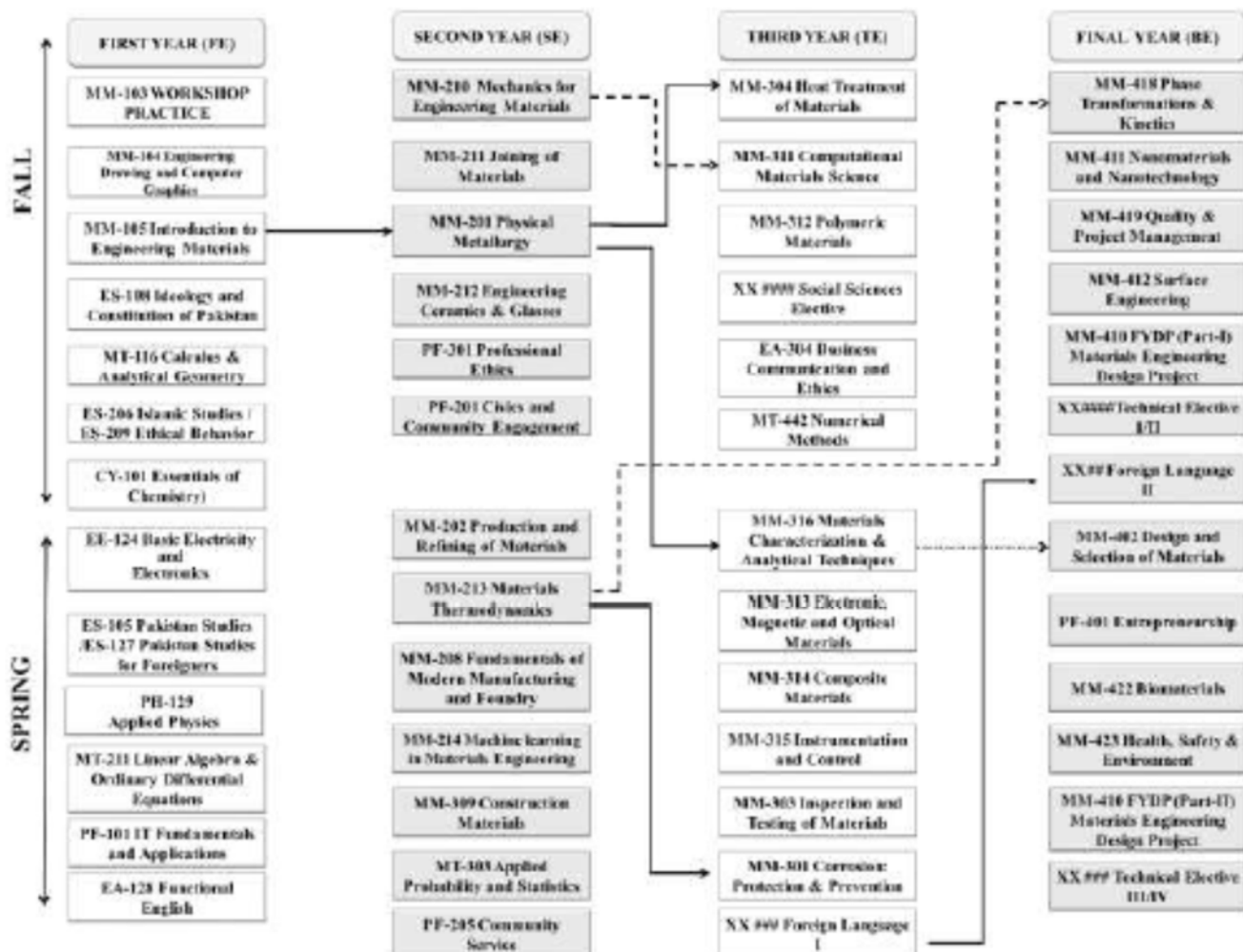
MM-422: **BIOMATERIALS**

Introduction to biomaterials and biochemistry; classification of natural and synthetic materials used in medical applications. Structure-property relationships of metals, ceramics, polymers, and composites. Key concepts include biocompatibility, bioactivity, biodegradability, bioresorbable and bioderodible materials. Study of hydrogels, smart polymers, and biomimetic materials. Basics of cell biology, surface properties, and intermolecular forces in biological systems. Material responses in the human body, mechanical effects on cells and tissues, and the role of water in biomaterials. Overview of biocompatible metals such as titanium alloys, stainless steels, Co-Cr-Mo alloys, and nitinol. Protein interaction with surfaces, porous and textured materials. Introduction to bioactive glasses, bio-resorbable ceramics, adhesives, and sealants. Applications in orthopedic, dental, cardiovascular, and tissue replacement. Overview of drug delivery systems, corrosion, blood-material interaction, and tumour responses.

DEPARTMENT OF MATERIALS ENGINEERING

Course Dependency Chart

Batch 2025 & onwards



Course title	Course Dependency
MM-165 Introduction to Engineering Materials	MM-201 Physical Metallurgy
MM-210 Mechanics for Engineering Materials	MM-311 Computational Materials Science
MM-201 Physical Metallurgy	MM-304 Heat Treatment of Materials MM-316 Materials Characterization & Analytical Techniques
MM-213 Materials Thermodynamics	MM-301 Corrosion: Protection & Prevention MM-418 Phase Transformations & Kinetics
MM-316 Materials Characterization & Analytical Techniques	MM-402 Design and Selection of Materials
XX-399 Foreign Language I	XX-399 Foreign Language II