DEPARTMENT OF POLYMER AND PETROCHEMMICAL ENGINEERING

SEMESTER SYLLABI OF COURSES
FOR
M.E. POLYMER PROGRAMME

NED UNIVERSITY OF ENGINEERING & TECHOLOGY,
KARACHI-75270

PAKISTAN

DEPARTMENT OF POLYMER AND PETROCHEMICAL ENGINEERING

Scheme of studies

a) **Title of the degree program:** Masters of Engineering in Polymer.
b) Credit Hour: One credit hour means one teaching hour
c) Duration of course:
Two and half year degree program consisting of 30 credit hours.
Thesis offered in 3rd semester.

Breakdown of the Compulsory and Elective courses

Compulsory and elective courses

Compulsory Courses		
Course No.	Course Title	Credit Hrs.
PP-511	Advanced Engineering Mathematics	3
PP-512	Advanced Polymer Processing	3
PP-513	Polymer Reactor Engineering	3
PP-514	Rheology of Complex Fluids	3
PP-515	Polymer Structure-Property Relationships	3
Elective Courses		
PP-525	Advanced Polymer Composites	3
PP-526	Fibre Technology	3
PP-527	Polymer Adhesives and Coatings	3
PP-528	Polymer Product Design	3
PP-529	Specialty and Functional Polymer Materials	3
PP-530	Rubber Technology	3
PP-531	Polymer Characterization	3
PP-532	Polymer Degradation, Stability and Recycling	3
ME-504	Project Management	3
PP-533	Process Safety & Loss Prevention	3
PP-534	Thermodynamics of Polymeric Systems	3
PP-535	Plastic Waste Management	3
PP-5002	Thesis	6
Non-Credit Course		
PP-401	Introduction to Polymeric Materials	3

COMPULSORY COURSE

PP-511: Advanced Engineering Mathematics

Linear Algebra: Algebra of matrices, inverse, rank, the system of linear equations, symmetric, skew-symmetric and orthogonal matrices, Hermitian, skew-Hermitian, unitary matrices, eigenvalues and eigenvectors, diagonalization of matrices, Cayley-Hamilton Theorem.Vector Calculus: Gradient, divergence and curl, vector identities, directional derivatives, line, surface, and volume integrals, Stokes, Gauss, and Green's theorems applications. Tensors: Tensor operations, vector operations using index notation, principal axes for Cartesian tensors, maximum shear stresses Differential equations and partial differential equations: Gamma functions, Bessel Functions, Legendre Functions, solutions to partial differential equations, and orthogonal functions. Advanced numerical methods: Brief review of numerical methods, finite difference methods for the solution of field problems, grid generation, and solution of initial value problem/boundary value problem with/without free, moving, or periodic boundaries, solution of stiff/coupled equations, finite element, and volume methods.

PP-512: Advanced Polymer Processing

Principles of Polymer Processing: Polymer melt flow in channels and cavities, Modelling, and analysis of various polymer processing operations (e.g., extrusion, injection molding, blow molding, thermoforming, compression molding, and fiber spinning). Processing of biaxially oriented polyethylene terephthalate (BOPET), biaxially oriented polypropylene (BOPP), and cast polypropylene (CPP) films. Reactive Polymer Processing: Polymer chain modification, basic principles, and equipment, examples of multicomponent immiscible and compatibilized immiscible polymer systems.

PP-513: Polymer Reactor Engineering

Introduction to Polymerization: Classes of polymerization, polymerization techniques, examples of some commercial polymers, and polymerization reactors. Principles of Polymer Reaction Engineering: Polymerization kinetics for step-growth and chain-growth mechanism under ideal and real conditions. Industrial Polymerization Reactors: Reactor classifications, key design issues, design considerations for homopolymers and random copolymers, polymerizations in a suspending phase. Reactor Scale-up, Analysis, and Modeling: Fundamental design equations of polymerization reactors, scale-up of commonly used industrial reactors, comprehensive process models.Case studies of some important industrial polymerization reactions.

PP-514: Rheology of Complex Fluids

Rheological Principals: Classifications of fluids behavior. Viscoelasticity: Linear viscoelasticity, viscoelastic models, relaxation spectrum, methods of measurement (static and dynamic methods), time-temperature superposition. Introduction to Non-linear Viscoelasticity: Nonlinear phenomena, simple non-linear rheological models Parameters Influencing Polymer Rheology: Factors affecting flow behavior (e.g., temperature, molecular weight distribution, additives, blend composition and morphology, etc.) The Role of Rheology in Polymer Processing: Melt flow index, flow analysis using rheological models, extensional viscosity and melt strength, rheological problems in co-extrusion (layer-to-layer non-uniformity, interfacial instability, trouble-shooting with the help of rheology. Rheometry: Viscometers and rheometers.

PP-515: Polymer Structure-Property Relationships

Polymer properties are affected by their chemical composition and molecular architecture. Polymer Structures/Morphology: Morphology-processing-property relationships (e.g., injection, blow molding, rotational molding, etc.), deformation mechanisms and orientation, the study of spherulites; thermodynamics and kinetic forces affecting polymer crystallization, physical techniques for studying crystal structure and morphology of polymers. Effect of Orientation and Crystallinity on Polymer Properties: Orientation in polymers (shear and tensile deformations). Molecular and structural requirements of polymers for formation of films, fibers, and multiphase systems.

ELECTIVE COURSES

PP-525: Advanced Polymer Composites

Overview of polymer composites and their fabrication. Factors influencing the performance of composites, structure-property relationship.Advanced mechanics of composites, classical lamination theory, analysis and failure of reinforced composite material systems, anisotropic elasticity, stress analysis, and design of laminated composites including 3D effects, stress concentrations, free-edge effects, hygrothermal behavior, adhesive and mechanical connections. Polymer Nanocomposites: Comparison with conventional composites, matrix materials, and nano-particulates, challenges in the production of polymer nanocomposites, characterization, applications, and future trends.

PP-526: Fiber Technology

Introduction: Raw materials and techniques used to produce fibers. Structural Principles of Polymeric Fibers: Orientation, crystallinity, and morphology. Theory of Polymeric Fiber Spinning: Chemistry of important fiber-forming polymers, thermodynamics of spinning, rheology and heat transport in spinning, and the effect of spinning parameters on fiber structure. Post-Spinning Operations: Drawing and heat-setting in thermoplastic fiber, the effect of various parameters on structure and properties of the fiber. Solution (Gel) Spinning: Comparison of solution spinning with other conventional spinning techniques, the effect of dope quality and spinning parameters on solution spinning, and solution spinning applications. Electro-Spinning: Effects of various parameters on electro-spinning, electro-spinning applications. Characterization of Fibers: Fiber density, optical and electron microscopy, thermal analysis, tensile properties, crystallinity, and orientation.

PP-527: Polymer Adhesives and Coatings

Formulation of Modern Coatings: Raw materials and polymer systems, selection of components. Film Formation: Theories of film formation, cross-linking, film defects, solvent evaporation, particle size effects. Types of Coatings: Solvent/water-borne, powder, radiation cure and architectural coatings, smart coatings, nano-coatings. Coating Application: Thermodynamics of interfaces, theories of application methods, substrate pre-treatment, adhesion, barrier properties, durability, corrosion protection, hiding and opacity, degradation of coatings. Regulatory considerations, volatile organic contents (VOCs). Adhesives: Adhesion theories, raw materials, compounding, substrate pre-treatment, adhesive selection, solvent and water-based adhesives, bond strength, and failure mechanisms.

PP-528: Polymer Product Design

Product Design: Effect of polymeric materials and their processing on product design, design methods considering fracture behavior, and deformation data.Design products based on different processing methods, welding, mechanical assembly, adhesive, and other fastening methods. Computer-Aided Engineering (CAE): Flow analysis software, finite element and volume analysis, modeling, and meshing for computer simulation.Cost Analysis: Part cost based on the material(s), process method and number of parts required, product development methodology, and tools.

PP-529: Specialty and Functional Polymer Materials

Liquid crystalline polymers, electrically conducting polymers, heat resistant polymers, polymeric membranes, polymers in biomedical engineering and their applications.Ionic polymers: Ionomers, ionic cross-linking, ion-exchange, ionic polymer-metal composites, applications.Polymers in textile finishing: Thickeners, binders, functional finishes, anti-microbial coatings, water-repellent, and flame-retardant coatings. Polymers in construction and agriculture: Polymers for concrete reinforcement, a polymer as thermal insulators, hydrogels, water-absorbing polymers, and polymer encapsulation of pesticides.

PP-530: Rubber Technology

Molecular basis for material to act as rubber, rubber elasticityMaterial Properties and Selection: Effects of the molecular structure of natural and synthetic rubbers.Compounding and vulcanization: Role of additives, processing, and product manufacture.Environmental and chemical resistance: Degradation of rubber compounds and methods of protection.Manufacturing techniques: Tires, belting, rubber to metal bonded components, Testing of raw materials, vulcanizates, and finished products as per international standards and service performance requirements.Thermoplastic Elastomers: Classification and applications.Rubber-Clay Nanocomposites: Synthesis, characterization, and applications.Recycling and re-use of waste rubber

PP-531: Polymer Characterization

Introduction and significance of polymer characterization for property determination. Molecular weight determination: Gel permeation chromatography (GPC), light scattering, and viscometry. Molecular spectroscopy: Overview, UV and visible spectroscopy, vibrational spectroscopy, and nuclear magnetic resonance (NMR). Thermal Characterization: Differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), dynamic mechanical, thermal analysis (DMTA). Microscopy: Optical and electron microscopy X-ray Diffraction: Wide angle and small-angle X-ray diffraction. Rheometry: Viscometers and

rheometers. Mechanical characterization: Mechanical testing of polymers (tensile testing, compression testing, 3-point, and 4-point bending testing, creep and stress relaxation test, impact test, micro, and macro hardness testing).

PP-532: Polymer Degradation, Stability and Recycling

Polymer Degradation: Chemical and physical factors affecting degradations, classification of degradation processes (thermal, photochemical, oxidative, and biodegradation), effects of degradation on polymer properties. Polymer Stabilization: Classification and mechanisms of stabilization. Polymer Recycling: Review of various commercial grades of plastics made from recycled sources, existing technologies for recycling, and energy recovery. Case studies of some industrially important plastics and rubber products. Global and local regulations for polymer recycling.

PP-533: Process Safety & Loss Prevention

Overview: Understanding risk, risk perception, acceptable risk, risk rating and ranking, risk matrix, Chemical process accidents.Process Safety-related Standards and Regulations: Impact of standards and regulations, OSHA process safety management standard, PSM and RMP background-based case studies. Process Safety Management (PSM) Standard: Introduction to the 14 Elements, OSHA PSM Requirement – Process Hazard Analysis (PHA), Difference between PSM and OSHA Regulations. Toxicology: Routes of entry, Causes and Effects, Toxicological studies Models of doses, Response curves, Threshold limit values. Source Models: Liquid discharge, Vapour discharge, Flashing liquids, Pool evaporation. Toxic Release and Dispersion Models: Design basis, Dispersion models, Weather effects, Release mitigation. Hazard Identification: Deviations from normal operation, Hazard and Operability Studies (HAZOP), Permit-to-work systems (PTWs), Lockout Tagout (LOTO), Procedure for Electrical and Mechanical Isolation Fires and Explosions: Fire triangle, Flammability characteristics of liquids and vapors, Ignition, Fire effects, Explosion mechanisms Fixed and portable fire extinguishers, Fire- Water System Design. Design to Prevent Accidents: Pressure relief, Inerting/purging, Controlling static electricity, Electrical hazards, and insulations, use of power tool, Ventilation. Risk and Reliability: On-site risk, Fatal Accident Rate (FAR), Off-site risk, Individual and societal risks, Quantitative risk assessment methods, Event tree analysis, Fault tree analysis, Bow tie analysis, Investigation Methodologies, Determining Root Causes, Structured Approach, Developing Effective Recommendations.Accident Investigation: Learning from accidents, Investigation process, and reporting, and Case studies.

PP-534: Thermodynamics of Polymeric Systems

Principles of thermodynamics in polymeric systems on both bulk and nanoscale, Thermodynamics of transitions in polymers. Thermodynamics of Polymer

solutions (dilute, semi-dilute, and concentrated solution): Conformation and molecular dimensions of polymer chains, solubility parameters, phase equilibria in polymer mixing, an extension of the Flory-Huggins theory, lower and upper critical solution temperatures. Thermodynamics of polymerization: Significance of thermodynamic variables in polymer processes, Polymerization depolymerization equilibria. Thermodynamics of Polymer Blends and Copolymers: Thermodynamics of homogeneous and heterogeneous polymer blends, critical fluctuations and spinodal decomposition, phase behavior of block copolymers.Thermodynamics of Polymer Matrix (nano) Composites: Thermodynamic stability and morphological development during industrially important nano- and conventional composites.

PP-535 Plastic Waste Management

Impact of plastics and microplastics on terrestrial and marine ecosystems, human health and biodiversity. The waste hierarchy in managing plastic waste, national and international context of sources and production of plastics waste, plastic circularity, optimizing materials and energy flow strategies at the production, consumption and end-of life stages, conventional versus modern practices in plastic waste management Life cycle assessments, sustainability challenges, eco-design principles, recyclability, role of upcycling in modern plastic waste management, current challenges and future of plastics and plastic waste, regulations for plastic waste management.

NON CREDIT COURSE

PP-401: Introduction to Polymeric Materials

Basic concepts in polymer science and engineering, Molecular weight, molecular weight distribution and its determination, Polymer synthesis, Kinetics and mechanism of polymerization processes, Crystallization in polymers and methods of its determination, Polymer mechanical & thermal properties and their determination, Polymer Processing.