CURRICULUM FOR THE UNDERGDAUATE DEGREE
DEPARTMENT OF POLYMER & PROCESS ENGINEERING

1 University Requirements (23 Credit Hours)

1.1 Science and Mathematics – 6 Credit Hours

A 100 level course from Mathematics Department		3(3,0)
A 100 level course from Physics or Chemistry Department		3(2,1)

1.2 Humanities and Social Sciences – 13 Credit Hours

HU 221	Technical Writing & Presentation Skills	3(3,0)
HU 111L	Communicational Skills	1(0,1)
IS 101	Islamic and Pakistan Studies I or HU 101 Ethics and Pakistan Studies-I	3(3,0)
IS 201	Islamic and Pakistan Studies II or HU 101 Ethics and Pakistan Studies-II	3(3,0)
A 300 or 400 level course of Management		3(3,0)

1.3 Computer Skills – 3 Credit Hours

One course on Computing		3(2,1)

1.4 Workshop Practice – 1 Credit Hour

ME 100L	Workshop Practice (Smithy, Machine, Fitter, Carpentry Shop, Electrical Shops & Model Making)	1(0,1)

2 Department Requirements (113 Credit Hours)

2.1 Management & Social Sciences – 6 Credit Hours

PPE-311	Engineering Economics	3(3,0)	
PPE-312	Engineering Management	3(3,0)	

2.2 Science and Mathematics Core – 6 Credit Hours

MA-118	Applied Mathematics & Statistics	3(3,0)	
MA-346	Numerical Methods	3(3,0)	

2.3 Departmental Core – 95 Credit Hours

PPE-101	Engineering & Polymeric Materials	3(3,0)	No Pre-requisite
PPE-102 & PPE-102L	Fundamentals of Polymer Engineering	4(3,1)	No Pre-requisite
PPE-103 & PPE-103L	Industrial Stoichiometry	4(3,1)	No Pre-requisite
PPE-104 & PPE-104L	Particle Technology	3(2,1)	No Pre-requisite
PPE-105	Petroleum Refining & Petrochemical Engineering	3(3,0)	No Pre-requisite
PPE-106 & PPE-106L	Fluid Flow	4(3,1)	No Pre-requisite
PPE-201 & PPE-201L	Polymer Structures & Synthesis	4(3,1)	CY-161
PPE-202	Polymer & Process Industries	3(3,0)	No Pre-requisite
PPE-203	Chemical Engineering Thermodynamics	3(3,0)	No Pre-requisite
PPE-204 & PPE-204L	Heat Transfer	4(3,1)	PPE-106
PPE-205 & PPE-205L	Mass Transfer	4(3,1)	PPE-106
PPE-206	Environmental Engineering & Process Safety	3(3,0)	PPE-202
PPE-301	Mechanical Properties of Polymers	3(3,0)	PPE-101
PPE-302 & PPE-302L	Polymer Reaction Engineering	4(3,1)	PPE-201
PPE-303	Polymer Compounding	3(3,0)	PPE-102
PPE-304 & PPE-304L	Simulation in Polymer Processing	3(2,1)	PPE-102
PPE-305	Polymer Thermodynamics	3(3,0)	PPE-203
PPE-306 & PPE-306L	Polymer Analysis & Characterization	4(3,1)	PPE-102
PPE-307	Transport Phenomena	3(3,0)	PPE-205
PPE-308 & PPE-308L	Polymer Processing Design	4(3,1)	PPE-102 & PPE-307
PPE-309 & PPE-309L	Process Engineering Computing	3(2,1)	PPE-204, PPE-205
PPE-310 & PPE-310L	Instrumentation & Control	4(3,1)	PPE-205
PPE-401	Polymer Rheology	3(3,0)	PPE-307
PPE-402	Polymer Product Design	3(3,0)	PPE-102, PPE-301
PPE-403 & PPE-403L	Process Plant Design	4(3,1)	PPE-204,-205,-302,311
PPE-404L	Plant Design Practice	3(0,3)	PPE-403 & PPE-403-L
PPE-405	Final Year Project-I	3(0,3)	PPE-201
PPE-406	Final Year Project-II	3(0,3)	PPE-405

2.4 Departmental Electives – 6 Credit Hours

PPE-407	Polymer Composites	3(3,0)	PPE-301
PPE-408	Smart Polymers	3(3,0)	PPE-201
PPE-409	Elastomeric Materials	3(3,0)	PPE-301
PPE-410	Polymers in Energy Applications	3(3,0)	PPE-201
PPE-411	Bio-Polymers	3(3,0)	PPE-201
PPE-412	Nano-Materials	3(3,0)	PPE-201

CURRICULUM DISTRIBUTION ACCORDING TO PEC-OBA MANUAL 2014

Knowledge Area	Subject	CH		CH Subject	Total CH	Required CHs
		Th	Lab			
Non-Engineering Domain						
Humanities	Technical Writing & Presentation Skills	3	0	3	16	19-21
	Communicational Skills	0	1	1		
	Engineering Economics	3	0	3		
	Environmental Engineering & Process Safety	3	0	3		
	Islamic and Pakistan Studies I	3	0	3		
	Islamic and Pakistan Studies II	3	0	3		
Management Sciences	Engineering Management	3	0	3	6	6
	Entrepreneurship	3	0	3		
Natural Sciences	Calculus and Analytic Geometry	3	0	3	22	19-20
	Applied Matehmatics & Statistics	3	0	3		
	Numerical Methods	2	1	3		
	Polymer Structures & Synthesis	3	1	4		
	Chemical Engineering Thermodynamics	3	0	3		
	Polymer Chemistry-I	2	1	3		
	Polymer Thermodynamics	3	0	3		
Total					**44**	**44-47**
Engineering Domain						
Computing	Introduction to Computing	2	1	3	9	9
	Process Engineering Computing	2	1	3		
	Simulation in Polymer Processing	2	1	3		
Engineering Foundation	Industrial Stoichiometry	3	1	4	30	29
	Engineering & Polymer Materials	3	0	3		
	Particle Technology	2	1	3		
	Polymer Analysis & Characterisation	3	1	4		
	Fundamentals of Polymer Engineering	3	1	4		
	Fluid Flow	3	1	4		
	Mechanical Properties of Polymers	3	0	3		
	Workshop Practice	0	1	1		
	Heat Transfer	3	1	4		
Major Based Core (Breadth)	Transport Phenomena	3	0	3	21	19-20
	Petroleum Refining & Petrochemical Engineering	3	0	3		
	Polymer Processing Design	3	1	4		
	Mass Transfer	3	1	4		
	Process Plant Design	3	1	4		
	Polymer Product Design	3	0	3		
Major Based Core (Depth)	Polymer Compounding	3	0	3	19	17-18
	Plant Design Pratice	0	3	3		
	Polymer Rheology	3	0	3		
	Polymer Reaction Engineering	3	1	4		
	Elective-I	3	0	3		
	Elective-II	3	0	3		
Interdisiplinary Engineering Breadth	Polymer & Process Industries	3	0	3	7	6-7
	Instrumentation and Control	3	1	4		
Senior Design Project	Final Year Project (FYP)	0	6	6	6	6
Industrial Training (Summer)		0	0	0	0	0
	Total				**92**	**86-89**
	Grand Total				**136**	**130-136**

MANAGEMENT & SOCIAL SCIENCES CORE

PPE-311 ENGINEERING ECONOMICS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. Introduction to engineering economics
2. Financing the corporate venture: *Business plans, sources of funds, debt versus equity financing*
3. Financial statements: *Accounting concepts and conventions, journal and ledger example, financial reports, financial ratios, a financial ratio example*
4. Estimation of capital requirements: *Land, fixed capital investment, estimation of fixed capital investment, scope and contingency, offsite capital, allocated capital, working capital, start-up expenses, other capital items*
5. Estimation of operating expenses: *Terminology, manufacturing expense sheet, estimation of operating expense items, company expense reports and expense standards, operating expense scale-up, operating expense index*
6. Time value of money: *Interest rate, interest nomenclature, simple interest, compound interest, compound interest factors, effective interest rates, changing interest rates, summary of compound interest factors, continuous interest, effective interest with continuous compounding, comparison of alternatives, capitalized cost*
7. Depreciation, depletion, amortization, and taxes: *Depreciation, history of depreciation methods, depreciation equations, depletion, amortization, taxes, tax credits*
8. Cash flow concept: *Cash flow model, comparison of alternatives, cumulative cash position plot, effect of the time value of money on the cash position plot, effect of cash flow on company operations*
9. Estimate of profitability: *Corporate objectives, project classification, minimum acceptable rate of return, profitability measures, concluding comments, illustrative problem*
10. Sensitivity and uncertainty analysis: *Sensitivity analysis, uncertainty analysis*
11. Feasibility analysis: *Information required, procedure, factors that affect the accuracy of a feasibility analysis, example of a feasibility analysis*
12. Choice between alternatives and replacement: *Theoretical discussion, calculation methods, out-of-pocket expenses, incremental analysis, replacement theory, opportunity cost*
13. The economic balance: *General procedure, practical considerations, general procedure for finding optimum conditions, procedure for solving single-variable balances, procedure with more than one controllable variable, interactive systems*

Textbook:

1. James Riley Couper, *Process Engineering Economics*, CRC Press, 2003 (ISBN-13: 978-0824740368)

Reference book:

2. Max Peters, Klaus Timmerhaus, Ronald West, *Plant Design and Economics for Chemical Engineers*, Fifth Edition, McGraw-Hill, 2002 (ISBN-13: 978-0072392661)

PPE-312 ENGINEERING MANAGEMENT

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

PART I INTRODUCTION TO ENGINEERING MANAGEMENT

1. Engineering and management: *Engineering, management, engineering management: a synthesis*
2. Historical development of engineering management: *The industrial revolution, management philosophies, scientific management, administrative management, behavioral management, contemporary contributions*

PART II FUNCTIONS OF TECHNOLOGY MANAGEMENT

1. Leading technical people: *Leadership, motivation, motivating and leading technical professionals*
2. Planning and forecasting: *Nature of planning, the foundation for planning, some planning concepts, forecasting, strategies for managing technology*
3. Decision making: *Nature of decision making, management science, tools for decision making, computer-based information systems, implementation*
4. Organizing: *Nature of organizing, traditional organization theory, technology and modern organization structures, teams*
5. Some human aspects of organizing: *Staffing technical organizations, authority and power, delegation, committees, teams*
6. Controlling: *The process of control, financial controls, human resource controls*

PART III MANAGING TECHNOLOGY

1. Managing research and development: *Product and technology life cycles, nature of research and development, research strategy and organization, selecting R&D projects, making R&D organizations successful, creativity, innovation, entrepreneurship*
2. Managing engineering design: *Nature of engineering design, systems engineering/new product development, concurrent engineering, control systems in design, design criteria*
3. Planning production activity: *Planning manufacturing facilities, quantitative tools in production planning, production planning and control, manufacturing systems*
4. Managing production operations: *Assuring product quality, total quality management, productivity, maintenance and facilities (plant) engineering*
5. Engineers in marketing and service activities: *Marketing and the engineer, engineers in service organizations*

PART IV MANAGING PROJECTS

1. Project planning and acquisition: *Characteristics of a project, the project proposal process, project planning tools, monitoring and controlling*
2. Project organization, leadership, and control: *Project organization, the project manager, motivating project performance, types of contracts*

PART V MANAGING YOUR ENGINEERING CAREER

1. Engineering ethics: *Professional ethics and conduct*
2. Achieving effectiveness as an engineer: *Getting off to the right start, charting your career, communicating your ideas, staying technically competent, professional activity, diversity in engineering and management, management and the engineer, managing your time*
3. Globalization and challenges for the future: *Globalization, engineering grand challenges*

Textbook:

1. Lucy C. Morse, Dan L. Babcock, Managing Engineering and Technology, Sixth Edition, Pearson Education Inc., 2014 (ISBN-13: 9780133485103)

SCIENCE AND MATHEMATICS CORE

MA-118 APPLIED MATHEMATICS AND STATISTICS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

PRE-REQUISITE

Algebra of complex numbers; Polar form of complex numbers; Algebra of matrices; Determinants and their properties; Crammer's rule. Algebra of vectors; Scalar and vector products.

CONTENTS

1. Product and quotient of complex numbers in polar form; Properties of complex numbers; Lograthim of a complex number; De Moivres Theorem, The nth roots of a number; Solution of equations.
2. A review of matrices, determinants and Crammer's rule: Inverse of a matrix through elementary row operations; Solution of the system of linear equations; Eigenvalues and eigenvectors.
3. Formation of differential equations; Solution of various types of first order differential equations; Orthogonal trajectories, Application in physical problems. Linear differential equations of second order, Complementary function and particular integral.
4. Formation of partial differential equations; Solution of equations reducible to ordinary differential equations.
5. Periodic functions. Even and odd functions. Fourier series of functions of period 2. Arbitrary period, half range series.
6. Scalar and vector triple products. Scalar and vector point functions; Differentiation and integration of vector point functions. Motion along a straight line with uniform acceleration, motion along a carved path. Tangential and normal components of acceleration; Simple harmonic motion.
7. Introduction & role of statistics in engineering. Frequency distributions; Measures of central tendency and dispersion; Regression; Probability with basic theory of distributions; Nomograms.

Textbook:

1. Erwin Kreyszig, *Advanced Engineering Mathematics*, Tenth Edition, Wiley, 2011 (ISBN: 9780470458365)

Reference books:

2. Muhammad Iqbal Bhatti & Muhammad Nasir, *Mathematics for Engineers and Scientists*, Allied Book Centre, Urdu Bazar Lahore.
3. Devore & Farnum, *Applied Statistics for Engineers & Scientists*, Third Edition
4. Pennisi, L. L. Holt, Rinehart and Winston, *Elements of Complex Variables*, U.S.A.
5. N. A. Shah, *Vector and Tensor Analysis*, A–One Publishers, Urdu Bazar, Lahore.

MA-346 NUMERICAL METHODS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. Overview of numerical techniques in engineering and its applications
2. Solution of non-linear equations: *Iteration, bracketing methods for locating roots, initial approximation and convergence criteria, Newton Raphson and Secant methods*
3. Interpolation and polynomial approximation: *Taylor series, intro to interpolation, Lagrange approximation, Newton polynomials, Chebyshev polynomials*
4. Curve fitting: *Least squares line, curve fitting, interpolation by spline functions, Fourier series and trigonometric polynomials*
5. Numerical differentiation: *Approximating the derivative*
6. Numerical integration: *Introduction to quadrature, composite trapezoidal and Simpsons rule, recursive rules and Romberg integration gauss Legendre integration*
7. Solution of differential equations: *Taylor series method, Eulers method, Runge-Kutta method and finite difference method*
8. Solution of partial differential equations: *Hyperbolic equations, parabolic equations, elliptic equations*

Textbooks:

1. S. C. Chapra & R. P. Canale, *Numerical Methods for Engineers*, McGraw-Hill.
2. John H. Mathews, *Numerical Methods using MATLAB*, Pearson Education.

Reference Books:

3. Robert J. Schilling & Sandra L. Harris, *Applied Numerical Methods for Engineers using MATLAB,* Brooks/Cole.
4. D. Joe Hoffman, *Numerical Methods for Engineers and Scientists*,
5. Saeed Akhtar Bhatti, *A First Course in Numerical Analysis with FORTRAN and C*

DEPARTMENTAL CORE

PPE-101 ENGINEERING AND POLYMERIC MATERIALS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. Introduction to materials and their properties: *Selection of materials, mechanical properties of materials, physical properties of materials, engineering materials, composite materials, factors affecting material properties, composition*
2. Basic science of materials: *Molecules and lattices, crystals , allotropy, grain structure, crystal growth, solidification defects, semiconductor materials, polymeric materials, polymer building blocks, crystallinity in polymers, orientation, melting points in polymers, glass transition temperature, the effect of temperature on polymer applications, memory effects*
3. Alloying of metals: *Alloys, alloying elements, solubility, solid solutions, intermetallic compounds, cooling curves, phase, alloy types, phase equilibrium diagrams (eutectic type, solid solution type, combination type), coring*
4. Plain carbon steels: *Ferrous metals, the iron-carbon system, critical change points, the effect of carbon on the properties of plain carbon steel, plain carbon steels*
5. Heat treatment of plain carbon steels: *Heat treatment processes, annealing processes, normalizing, quench hardening, quenching media, tempering, mass effect, case hardening, localized case hardening, surface hardening*
6. Cast irons and their heat treatment: *The iron-carbon system for cast iron, alloying elements and impurities, heat treatment of grey cast iron, malleable cast iron, alloying cast irons, properties and uses of white and grey cast irons, specifications of grey iron castings, properties uses of malleable cast irons, specifications of malleable cast irons, compositions*
7. Non-ferrous metals their alloys and their heat treatment: *Non-ferrous metals, aluminum, aluminum alloys, copper, high copper content alloys, brass alloys, tin-bronze alloys, aluminum-bronze alloys , cupro-nickel alloys, magnesium alloys, zinc alloys, tin-lead alloys*
8. Polymeric materials: *The history of plastics, additives , fillers , stabilizers, colorants, antistatic agents , general properties of polymeric materials (electrical insulation, strength/weight ratio, corrosion resistance), properties and application of elastomers, commercial elastomers, properties and applications of typical thermoplastics, properties and applications of typical thermosetting plastics*
9. Composite materials: *Introduction, lamination, plywood, laminated plastic, fiber reinforcements, particle reinforcements*
10. Shaping and joining materials: *Molding polymeric materials, welding plastic materials, adhesive bonding, thermoplastic adhesives, impact adhesives, thermosetting adhesives, safety in the use of adhesives*
11. Materials testing (destructive): *Properties of materials, tensile strength and interpretation of tensile test results, impact testing, hardness testing, the effect of processing on hardness, comparative scales of hardness , ductility testing*
12. Materials testing (non-destructive): *The need for non-destructive testing, visual examination, ultrasonic testing, magnetic testing, radiography*
13. Materials in service : *Allowable working stress, creep in polymeric materials, fatigue, factors affecting fatigue of metals and polymers, the corrosion of metals, types of corrosion factors affecting corrosion, prevention from corrosion, plastic degradation*

Textbook:

1. R. L. Timings, *Engineering Materials, Volume 1*, Second Edition, Longman, 1998 (ISBN-13: 978-0582319288)

PPE-102 & PPE-102L FUNDAMENTALS OF POLYMER ENGINEERING

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

SECTION-I POLYMER FUNDAMENTALS

(a) Types of polymers: *Thermoplastics and thermosets, chemistry of synthesis, structure*
(b) Molecular structure of polymers: *Types of bonds, bond distances and strengths, bonding and response to temperature, action of solvents, bonding and molecular structure, stereoisomerism*
(c) Polymer morphology: *Amorphous and crystalline polymers, the effect of polymer structure, temperature, and solvent on crystallinity, the effect of crystallinity on polymer density, the effect of crystallinity on mechanical properties, the effect of crystallinity on optical properties, models for the crystalline structure of polymers, extended chain crystals, liquid crystal polymers*
(d) Characterization of molecular weight: *Average molecular weights, determination of average molecular weights, molecular weight distributions, gel permeation (or size-exclusion) chromatography (GPC, SEC)*
(e) Thermal transitions in polymers: *The glass transition, molecular motions in an amorphous polymer, determination of Tg, factors that influence Tg, the effect of copolymerization on Tg, the thermodynamics of melting, he metastable amorphous state, the influence of copolymerization on thermal properties, effect of additives on thermal properties, effects of crosslinking, thermal degradation of polymers*
(f) Rheological behavior of polymers and viscoelasticity: *Relations between shear force and shear rate, polymer melts and solutions, power law for non-Newtonian fluids, temperature dependence of flow properties, influence of molecular weight on flow properties, the effects of pressure on viscosity, viscous energy dissipation, introduction to linear viscoelasticity*
(g) Mechanical properties of polymers: *Introduction to mechanical properties of polymers*

SECTION -II POLYMER PROCESSING AND PERFORMANCE

(a) Introduction to polymer processing
(b) Polymer applications: *Plastics and plastic additives, rubbers and thermoplastic elastomers, synthetic fibers, surface finishes and coatings, adhesives*

SECTION -III POLYMER PROPERTIES AND SINGLE-POINT TESTING

(a) Analytical tests: *Density and specific gravity, water absorption, moisture analysis, sieve analysis, pourability of plastic materials*
(b) Material characterization tests: *melt flow index (MFI), viscometer*
(c) Mechanical tests: *Tensile testing, flexural testing, creep and stress relaxation, impact testing, hardness*
(d) Thermal properties: *Heat deflection temperature, Vicat softening point, melting point, thermal conductivity, thermal expansion, brittleness temperature*
(e) Electrical properties: *Dielectric strength, dielectric constant and dissipation factor*
(f) Weathering properties: *Accelerated weathering and out-door weathering*
(g) Optical properties: *Refractive index, luminous transmittance and haze, color, gloss*
(h) Chemical properties: *Immersion tests, solvent stress-cracking resistance, environmental stress-cracking resistance*

Textbooks:

1. Christopher S. Brazel, Stephen L. Rosen, *Fundamental Principles of Polymeric Materials*, Third Edition, John Wiley & Sons, Inc., 2012 (ISBN-13: 978-0470505427)
2. Alberto Naranjo et. al., *Plastic Testing and Characterization: Industrial Applications*, Carl Hanser Verlag, Munich, 2008 (ISBN-13: 978-1569904251)

Reference book:

3. Vishu Shah, *Handbook of Plastics Testing and Failure Analysis*, Third Edition, John Wiley & Sons, Inc., 2007 (ISBN-13: 978-0471671893)

LABORATORY:

The laboratory section involves the single-point testing of polymeric materials according to ASTM and ISO standards. The testing performed in this lab includes:

(a) Analytical tests: Density and specific gravity, moisture analysis, pourability of plastic materials
(b) Material characterization tests: melt flow index (MFI), viscometer
(c) Mechanical tests: Tensile testing, impact testing, hardness
(d) Thermal properties: Heat deflection temperature, Vicat softening point, melting point
(e) Electrical properties: Surface and volume resistance

PPE-103 & PPE-103L INDUSTRIAL STOICHIOMETRY

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

SECTION-I INTRODUCTION

(a) Dimensions, units and their conversion
(b) Moles, Density and Concentration
(c) Choosing a basis
(d) Temperature
(e) Pressure

SECTION-II MATERIAL BALANCES

(a) Introduction to material balances: *The concept of a material balance , open and closed system , steady state and unsteady sate systems, multiple component systems, accounting for chemical reactions in material balances , material balance for batch and semi-batch processes*
(b) A general strategy for solving material balance problems: *Problem solving, The strategy for solving problems*
(c) Solving material balance problems for single units without reactions: *Main concepts regarding solving material balance problems for single units without reactions*
(d) The chemical reaction equation and stoichiometry: *Stoichiometry, terminology for applications of stoichiometry*
(e) Material balances for processes involving reactions
(f) Material balance problems involving multiple units
(g) Recycle, bypass, purge and the industrial application of material balances

SECTION-III ENERGY BALANCES

(a) Energy terminology, concepts and units: *The terminology associated with energy balances , types of energy*
(b) Introduction to energy balances for processes without reaction: *The concept of the conservation of energy, energy balances for closed steady state and unsteady state systems, energy balances for open steady state and unsteady state systems*
(c) Calculation of enthalpy changes: *Phase transitions, heat capacity equations, tables and charts to retrieve enthalpy values , computer databases*

(d) Energy balances: How to account for chemical reaction*: The standard heat of formation, the heat of reaction, merging the heat of formation with the sensible heat of a compound in making energy balance, the heat of combustion*
(e) Humidity (Psychrometric) charts: Terminology, the humidity, applications of humidity chart
(f) Solving simultaneous material and energy balances : Analyzing *the degree of freedom in a steady state process, solving material and energy balances using flow-sheeting codes*

Textbook:

1. David M. Himmelblau, James B. Riggs, *Basic Principles and Calculations in Chemical Engineering*, Eighth Edition, Prentice Hall, 2012 (ISBN-13: 978-0132346603)

Reference books:

2. O. A. Hougen, K. M. Watson, and R. A. Ragatz, *Chemical process principles-part 1, Material and Energy Balances.*, Second Edition, John Wiley & Sons, Inc., 1954
3. Richard M. Felder, Ronald W. Rousseau, *Elementary Principles of Chemical Processes*, Third Edition, Wiley, 2005 (ISBN-13: 978-0471720638)

LABORATORY:

The laboratory section involves the practice of the problems related to stoichiometric calculations under the supervision of an instructor. Computer software like Microsoft Excel may be used for the calculations.

PPE-104 & PPE-104L PARTICLE TECHNOLOGY

Credit Hours: 3 (Theory = 2, Laboratory = 1), Contact Hours: 5 (Theory = 2, Laboratory = 3)

SECTION-I PROPERTIES AND HANDLING OF PARTICULATE SOLIDS

(a) Characterization of solid particles
(b) Properties of masses of particles: *Storage and conveying of solids*
(c) Mixing of solids: *Mixing performance, mixers for Non-cohesive solids, mixers for cohesive solids*
(d) Mixing techniques and mixers for polymers and elastomers: *Mixer extruder, muller mixer, mixing effectiveness, axial mixing*

SECTION-II SIZE REDUCTION

(a) Introduction to crushing, grinding and size separation: *Characteristic of comminuted products, energy and power requirements in comminution, crushing laws and work index*
(b) Equipment for size reduction: *Crushers and types, grinders and types, roller mill, attrition mill, tumbling mill, ultrafine grinders, classifying hammer mill, fluid energy mill, agitated mill, colloid mill, cutting machines, energy consumption, size enlargement*

SECTION-III MECHANICAL SEPARATIONS

(a) Screening: *Screening equipment, vibrating screens, screen capacity*
(b) Filtration: *General considerations*
(c) Cake filters*: Centrifugal filters, filter media, filter aids, Principles of cake filtration, washing filter cakes*
(d) Clarifying filters: Liquid clarification, gas cleaning, principles of clarification
(e) Cross-flow filtration: *Membrane filters, types of membranes, premeate flux for ultrafilteration, concentration polarization, applications of ultrafilteration, diafileration, microfilteration*
(f) Gravity sedimentation processes
(g) Centrifugal sedimentation processes

SECTION-IV CRYSTALLIZATION

(a) Crystal geometry
(b) Equilibria and yields
(c) Nucleation
(d) Crystal growth
(e) Origins of crystals in crystallizers
(f) Crystallization equipment
(g) Crystallizer design: *Crystal size distribution*
(h) Crystallization from melts

Textbook:

1. Warren L. McCabe, Julian Smith, Peter Harriott, *Unit Operations of Chemical Engineering*, Seventh Edition, McGraw-Hill, 2004 (ISBN-13: 978-0072848236)

Reference books:

2. R. G. Holdich, *Fundamentals of Particle Technology*, Midland Information Technology and Publishing, 2002 (ISBN: 0954388100)
3. Edward L. Paul, Victor A. Atiemo-Obeng, Suzanne M. Kresta, Handbook of Industrial Mixing: Science and Practice, John Wiley & Sons, Inc., 2003 (ISBN: 978-0-471-26919-9)
4. J H Harker, J R Backhurst, J.F. Richardson, *Coulson and Richardson's Chemical Engineering Volume 2*, Fifth Edition, Butterworth-Heinemann, 2002 (ISBN-10: 0750644451)

LABORATORY:

The laboratory section involves the experiments on the equipment related to the unit operations involving particle technology.

PPE-105 PETROLEUM REFINING AND PETROCHEMICAL ENGINEERING

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

SECTION-I PETROLUEM REFINING

1. Introduction to refinery products and feedstock
2. Crude distillation
3. Coking and thermal cracking: *Types, properties and uses of petroleum coke, delayed coking, flexi-coking, fluid coking, vis-breaking*
4. Catalytic cracking: *Fluidized bed catalytic cracking , cracking reactions, cracking of paraffins, olefin, naphthenic and aromatic hydrocarbons, cracking catalysts*
5. Catalytic hydrocracking: *Hydrocracking reactions, the hydrocracking process, hydrocracking catalyst, process variables*
6. Hydro-treating: *Hydro-treating catalysts, aromatic reduction, reactions, process variables*
7. Catalytic reforming and isomerization: C*atalytic reforming processes, reforming catalyst, isomerization*
8. Lubricating oil blending stocks: *Lube oil processing, propane de-asphalting, de-waxing, hydro-finishing*
9. Petrochemical feed-stocks: *Aromatics production, unsaturate production, saturated paraffins*

SECTION-II PETROCHEMICAL ENGINEERING

1. Primary raw materials for petrochemicals: *Natural gas, crude oils, coal, oil shale, tar sand, and gas hydrates*
2. Hydrocarbon intermediates: *Paraffinic hydrocarbons, olefinic hydrocarbons, dienes, aromatic hydrocarbons*
3. Chemical based on Methane: *Chemicals based on direct reactions on methane, chemicals based on synthesis gas*
4. Ethane and higher paraffins based chemicals: *Ethane chemicals, propane chemicals, n butane chemicals, isobutene chemicals, naphtha based chemicals*
5. Chemicals based on ethylene: *Oxidation of ethylene, chlorination of ethylene, alkylation using ethylene*
6. Chemicals based on Propylene: *Oxidation of propylene, Chlorination of Propylene, Alkylation of propylene*
7. C_4 Olefins and Di-olefins based chemicals: *Chemicals based on n butenes, isobutylenes and butadiene*
8. Chemicals based on benzene, toluene and xylene: *Reactions and chemicals of benzene , toluene and xylenes*
9. Synthetic petroleum based polymers: *Thermoplastics and engineering resins, thermoplastic plastics , synthetic rubber, synthetic rubbers*

Textbooks:

1. James H. Gary, Glenn E. Handwerk, Mark J. Kaiser, *Petroleum Refining: Technology and Economics*, Fifth Edition, CRC Press, 2007 (ISBN-13: 978-0849370380)
2. Sami Matar, Lewis F. Hatch, *Chemistry of Petrochemical Processes*, Second Edition, Gulf Professional Publishing, 2001 (ISBN-13: 978-0884153153)

PPE-106 & PPE-106L FLUID FLOW

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

1. Introduction: *Basic properties of fluids, introduction to fluid flow, fluid and solid, molecular structures of fluid and solid, classification of fluids, dimensions associated with common physical quantities, an application of fluid flow, introduction to fluid statics, basics of hydrostatic equilibrium*
2. Fluid flow phenomena: *Ideal fluid and potential flow , the velocity field, one-dimensional flow, the shear stress field, viscosity, kinematic viscosity, turbulence, viscosity and momentum flux, characteristics of turbulent flows, turbulence & boundary layers, nature of turbulence, deviating velocities in turbulence flow, eddy viscosity, flow in boundary layers, development of turbulent boundary layer on a flat plate, boundary-layer formation in straight tubes, boundary-layer separation and wake formation, numerical and examples*
3. Basic equations of fluid flow: *Mass balance in a flowing fluid, macroscopic momentum balance, momentum correction factor, Bernoulli's equation without friction, correction of Bernoulli's eq. for fluid friction, skin and form friction, pump work in Bernoulli's equation*
4. Flow of incompressible fluids in conduits and in thin layers: *Incompressible flow in pipes and channels, shear stress and skin friction in pipes, relation between skin friction and wall shear, the friction factor, relation between skin friction parameters, laminar flow in pipes, Hagen-Poiseuille eq., effect of roughness, drag reduction in turbulent flow, friction from changes in velocity or direction, numerical and problems*
5. Flow of compressible fluids: *Processes of compressible flow, flow through variable area conduits, adiabatic frictional flow, isothermal frictional flow*
6. Flow past immersed bodies: *Friction in flow through beds of solids, motion of particles through fluids, fluidization*
7. Transportation and metering of fluids: *Pipes, fittings and valves, fluid-moving machinery: pumps, positives-displacement pumps, centrifugal pumps, fans, blowers and compressors, measurements of flowing fluids: full-bore meters, insertion meters*
8. Agitation and mixing of liquids: *Agitation of liquids, circulation, velocities and power consumption in agitation vessels, blending and mixing, suspension of solid particles, dispersion operations*

Textbook:

1. Warren L. McCabe, Julian Smith, Peter Harriott, *Unit Operations of Chemical Engineering*, Seventh Edition, McGraw-Hill, 2004 (ISBN-13: 978-0072848236)

LABORATORY:

The laboratory section involves the hands-on training and experimentation on the equipment related to the unit operations relevant to fluid flow under the supervision of an instructor.

PPE-201 & PPE-201L POLYMER STRUCTURES & SYNTHESIS

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

SECTION-I STATES OF ORDER IN POLYMERS

(a) Macromolecules in solution
(b) Macromolecules in the molten state
(c) Macromolecules in the solid state: *Macromolecules in the elastomeric state, macromolecules in the amorphous (glassy), macromolecules in the crystalline state*

SECTION-II METHODS AND TECHNIQUES FOR SYNTHESIS OF POLYMERS

(a) Methods for synthesis of polymers: *Chain growth polymerizations, step growth polymerizations, modification of polymers*
(b) Techniques for manufacturing of polymers: *Particularities in the preparation of polymers, polyreactions in bulk, homogeneous polyreactions in bulk, heterogeneous polyreactions in bulk, polyreactions in solution, polyreactions in dispersion, polyreactions in suspension, polyreactions in emulsion*
(c) General laboratory techniques for the preparation of polymers
(d) Correlations of structure and morphology with the properties of polymers

SECTION-III SYNTHESIS OF MACROMOLECULES BY CHAIN GROWTH POLYMERIZATION

(a) Radical homopolymerization
(b) Ionic homopolymerization
(c) Ring-opening polymerization
(d) Metal-catalyzed polymerization including polymerization with Ziegler-Natta-catalysts
(e) Copolymerization
(f) Kinetics of chain growth polymerization

SECTION-IV SYNTHESIS OF MACROMOLECULES BY STEP GROWTH POLYMERIZATION

(a) Condensation polymerization (poly-condensation): *Polyesters, polyamides, phenol-formaldehyde resins, urea- and melamine-formaldehyde condensation products*
(b) Stepwise addition polymerization (poly-addition): *Polyurethanes, epoxy resins*
(c) Kinetics of step growth polymerization

SECTION-V MODIFICATION OF MACROMOLECULAR SUBSTANCES

(a) Chemical conversion of macromolecules
(b) Crosslinking of macromolecular substances
(c) Degradation of macromolecular substances
(d) Modification of polymers by additives
(e) Mixtures of polymers (polymer blends)
(f) Stretching and foaming of polymers

Textbook:

1. Dietrich Braun, Harald Cherdron, Matthias Rehahn, Helmut Ritter, Brigitte Voit, *Polymer Synthesis: Theory and Practice: Fundamentals, Methods, Experiments*, Fifth Edition, Springer, 2013 (ISBN-13: 978-3642289798)

Reference book:

2. George Odian, *Principles of Polymerization*, Fourth Edition, Wiley-Interscience, 2004 (ISBN-13: 978-0471274001)

LABORATORY:

The laboratory section involves the synthesis of common polymers including polystyrene, poly (methyl methacrylate), polyester, polyaniline followed by characterization of the resultant polymer using FTIR, DSC, TGA etc.

Reference book for the laboratory:

3. Stanley R. Sandler , Wolf Karo, JoAnne Bonesteel , Eli M. Pearce, *Polymer Synthesis and Characterization Manual*, Academic Press, 1998 (ISBN-13: 978-0126182408)

PPE-202 POLYMER & PROCESS INDUSTRIES

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

SECTION-I FUNDAMENTALS OF CHEMICAL PROCESSING

(a) Batch versus continuous processing
(b) Chemical process control and instrumentation
(c) Process flow sheeting
(d) Chemical process economics

SECTION-II POLYMER INDUSTRIES

(a) Man-made fiber and film industries: *Manufacturing processes of synthetic fibers, cellulosic fibers, finishing and dying of textiles, manufacturing of polymer films*
(b) Surface-coating industries: *Paints manufacturing, varnishes, lacquers, printing inks and industrial polishes*
(c) Adhesive and polymer packaging industry: *Adhesive manufacturing, industrial processes for the production of polymer packaging*
(d) Extrusion: *Introduction, equipment, normal operations and control of the process, extrusion problems and troubleshooting, special extrusion processes and products, case studies*
(e) Injection molding: *Introduction, equipment, normal operations and control of the process, critical operational parameters and techniques, injection molding problems and troubleshooting, case studies*
(f) Blow molding: *Introduction, extrusion blow molding, injection blow molding, blow molding problems and troubleshooting, case studies*
(g) Thermoforming: *Forming processes, equipment, plant considerations, normal operations and control, thermoforming problems and troubleshooting, film thermoforming processes and products, case studies*
(h) Foaming: *Introduction, creating foams in resins, shaping and solidifying foams, re-bond, applications, case studies*
(i) Polymer composites: *Composite materials, manufacturing methods for composite parts, case studies*
(j) Rubber industries: *Natural rubber, synthetic rubber, rubber compounding processes, rubber-products fabrication, latex compounds, reclaimed rubber, rubber derivatives*

SECTION-III PROCESS INDUSTRIES

(a) Water treatment industries: *Types of impurities in water from various resources*
(b) Fertilizer industries: *Synthetic ammonia, phosphate rock, super phosphate, potassium sulfate, potassium chloride, ammonium nitrate, ammonium sulfate, ammonium sulfate and Urea manufacturing processes*
(c) Explosives and propellants industries: *Types and characteristics of explosives, industrial explosives, propellants for rockets, military explosives*
(d) Pulp and paper industries: *Manufacturing of pulp, manufacturing of paper, manufacturing of structural boards*
(e) Food and food by-products processing industries: *Types of food processing, pasteurization and sterilization, food by-products, food processing equipment*
(f) Sugar and starch industries: *Manufacture of sugar, cane-sugar refining processes, starches and related products, manufacturing of starch, dextrin, and dextrose from corn*

Textbooks:

1. G. T. Austin, *Shreve's Chemical Process Industries*, Fifth Edition, McGraw-Hill Professional, 1998 (ISBN-13: 978-0071350112)
2. A. Brent Strong, *Plastics: Materials and Processing*, Third Edition, Prentice Hall, 2005 (ISBN-13: 978-0131145580)

PPE-203 CHEMICAL ENGINEERING THERMODYNAMICS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. Introduction: *The scope of thermodynamics, dimensions and units, measures of amount or size, force, temperature, pressure, energy, heat*
2. The first law and related concepts: *Joule's experiments, internal energy, the first law of thermodynamics, the energy balance for closed systems, the thermodynamic state and state functions, equilibrium, the phase rule, the reversible process, constant-V and constant-P processes, enthalpy, heat capacity, mass and energy balances for open systems*
3. Volumetric properties of pure fluids: *PVT behavior of pure substances , virial equations of state, the ideal gas, application of the virial equations, cubic equations of state, generalized correlations for gases, generalized correlations for liquids*
4. Heat effects: *Sensible heat effects, latent heats of pure substances, standard heat of reaction, standard heat of formation, standard heat of combustion, temperature dependence of standard heat, heat effects of industrial reactions*
5. The second law of thermodynamics: *Statements of the second law, heat engines ,thermodynamic temperature scales, entropy, entropy changes of an ideal gas, mathematical statement of the second law, entropy balance for open systems, calculation of ideal work, lot work, the third law of thermodynamics, entropy from the microscopic viewpoint*
6. Thermodynamic properties of fluids: *Property relations for homogeneous phases, residual properties*
7. Applications of thermodynamics to flow processes: *Duct flow of compressible fluids, turbines, compression processes*
8. Production of power from heat transfer: *The steam power plant, internal – combustion engine, jet engines, rocket engines*
9. Refrigeration and liquefaction: *The Carnot refrigerator, the vapor compression cycle, the choice of refrigeration, absorption, the heat pump, liquefaction processes*
10. Chemical reaction equilibria: *The reaction coordinate, application of equilibrium criteria to chemical reaction, the standard Gibbs energy change and the equilibrium constant , effect of temperature on the equilibrium constant, evaluation of equilibrium constants, relation of equilibrium constants to composition, equilibrium conversions for single reactions, multi-reaction equilibria, fuel cells*

Textbook:

1. J.M. Smith, Hendrick Van Ness, Michael Abbott, *Introduction to Chemical Engineering Thermodynamics*, Seventh Edition, McGraw-Hil, 2004 (ISBN-13: 978-0073104454)

PPE-204 & PPE-204L HEAT TRANSFER

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

SECTION-I

(a) Heat transfer by conduction in solids: *Basic law of conduction, thermal conductivity, steady state conduction and unsteady state conduction*

(b) Principles of heat flow in fluids : *Typical heat exchange equipment, heat flux and heat transfer coefficients*

SECTION-II

(a) Heat transfer to fluids without phase change: *Boundary layers, heat transfer by forced convection in turbulent flow, effect of roughness, natural convection and heating and cooling of fluids in forced convection*

(b) Heat transfer to fluids with phase change: *Heat transfer from condensing vapors, drop-wise and film type condensation, Nusselt equations, heat transfer to boiling liquids, sub-cooled boiling , pool boiling, thermo-siphon re-boilers and forced circulation re-boilers*

SECTION-III

(a) Radiation heat transfer: *Fundamental facts concerning radiation, emission of radiation, wavelength of radiation and emissive power*
(b) Blackbody radiation: *Emissivity of solids, practical source of blackbody radiation, laws of blackbody radiation, absorption of radiation by opaque solids, Krichhoff's law*
(c) Combined heat transfer by conduction, convection and radiation

SECTION-IV

(a) Heat-exchange equipment: *General design of heat exchange equipment, shell and tube heat exchangers, 1-1 exchanger, tube and tube sheets, shell and baffles, multipass exchangers and 2-4 exchangers*
(b) Correlations of LMTD in multi-pass exchangers: *Heat transfer coefficients in shell and tube exchangers, choice of tube side fluid, cross-flow exchangers*
(c) Types of heat exchangers: *Plate type exchangers, extended surface equipment, type of extended surface and scraped surface exchangers*
(d) Condensers and vaporizers

SECTION-V

(a) Evaporation: *Types of evaporators, single effect and multiple effect evaporators, performance of tubular evaporators , methods of feeding and vapor recompression*
(b) Drying of solids: *Solids handling in dryers, principles of drying, heat transfers in dryers, equilibrium moisture and free moisture*

Textbook:

1. Warren L. McCabe, Julian Smith, Peter Harriott, *Unit Operations of Chemical Engineering*, Seventh Edition, McGraw-Hill, 2004 (ISBN-13: 978-0072848236)

Reference books:

2. D. Q. Kern, *Process Heat Transfer*, McGraw-Hill, 1950 (ISBN: 9780074632178)
3. J. M. Coulson and J. F. Richardson, *Coulson & Richardson's Chemical Engineering: Fluid Flow, Heat Transfer, and Mass Transfer,* Butterworth-Heinemann, Sixth Edition, 1999 (ISBN: 9780750644440)

LABORATORY:

The laboratory section involves the hands-on training and experimentation on the equipment related to the unit operations relevant to heat transfer e.g. shell and tube heat exchanger, plate-and-frame heat exchanger, under the supervision of an instructor.

PPE-205 & PPE-205L MASS TRANSFER

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

SECTION-I

(a) Mass transfer and application: *Introduction and types of separation processes*
(b) Principles of diffusion and mass transfer between phases : P*hase equilibria, theory of diffusion, Fick's law of diffusion, equimolal diffusion, one component mass transfer, prediction of diffusivities in different materials, mass transfer theories, film theory, boundary layer theory, penetration theory and two film theory*

SECTION-II

(a) Gas absorption: *Principle of absorption, types of packing and packed tower*

(b) Humidification operations: *Humidity chart, wet bulb temperature, psychrometric lines, measurement of humidity with different methods, dew point methods, psychrometric methods, direct method and cooling towers*

SECTION-III

(a) Equilibrium stage operations: *Typical distillation equipment, typical leaching equipment, principles of stage processes, graphical methods for two component systems, operating line diagrams, determination of ideal contact stages*

(b) Distillation: *Flash distillation, continuous distillation with reflux, rectification and stripping, number of ideal plates by McCabe-Thiele method, conditions of feed, feed line, construction of operating line, feed plate location, minimum number of plates, minimum reflux, optimum reflux ratio, normal operations of sieve plates, valve trays column, types of plate efficiency, Murphree efficiency, distillation in packed columns, , introduction to multicompnent distillation, batch distillation, azeotropic and extractive distillation*

SECTION-IV

(a) Leaching and extraction: *Leaching, leaching equipment, principles of countercurrent leaching, liquid extraction, extraction equipment, principles of extractions, phase equilibrium and special extraction techniques*

SECTION-V

(a) Drying of Solids: *Drying equipment, cross circulating drying, rates of drying, dryers for solids and pastes, tray dryers, screen conveyers dryers, tower dryers, rotary dryers, fluid bed dryers, flash dryers, dryers for solutions and slurries*

SECTION-VI

(a) Membrane separation processes: *Separation of gases, porous membranes, polymer membranes, membrane structure, flow patterns in membrane separators, separation of liquids, dialysis, pervaporation, reverse osmosis*

Textbook:

1. Warren L. McCabe, Julian Smith, Peter Harriott, *Unit Operations of Chemical Engineering*, Seventh Edition, McGraw-Hill, 2004 (ISBN-13: 978-0072848236)

Reference books:

2. D. Basmadjian, *Mass Transfer: Principles and Applications*, Taylor & Francis, 2003 (ISBN: 9780203503140)
3. E. J. Henley, J. D. Seader and D. K. Roper, *Separation Process Principles*, Wiley, 2011(ISBN: 9780470646113)
4. J. M. Coulson and J. F. Richardson , *Coulson & Richardson's Chemical Engineering: Fluid Flow, Heat Transfer, and Mass Transfer,* Butterworth-Heinemann, Sixth Edition, 1999 (ISBN: 9780750644440)

LABORATORY:

The laboratory section involves the hands-on training and experimentation on the equipment related to the unit operations relevant to mass transfer e.g. distillations, gas absorption, under the supervision of an instructor.

PPE-206 ENVIRONMENTAL ENGINEERING & PROCESS SAFETY

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

SECTION-I ECOLOGY OF ENVIRONMENT

(a) Air pollution: E*ffects of air pollutants, origins and fates of air pollutants, acid rain, ozone depletion, global warming, air pollution meteorology, atmospheric dispersion*

(b) Water pollution: *Causes of water pollution, water treatment, water quality and standards, water plant waste management, water pollution sources, biological oxygen demand*

SECTION-II MANAGEMENT OF POLYMER WASTE

(a) Environmental issues related to the plastics industry
(b) The polymer waste problem
(c) Legislation
(d) Disposing of post-consumer plastics
(e) Life-cycle assessment
(f) Plastics recovery and recycling
(g) Mechanical recycling
(h) Reprocessing of mixed plastics wastes
(i) Energy recovery by incineration
(j) Liquid fuel and feedstock recovery
(k) Management of urban waste

SECTION-III PROCESS SAFETY

(a) Importance of safety and health for engineers: *Occupational safety and health, environmental problems*

(b) Toxicology: *Effects of toxicants on biological organisms, relative toxicity, threshold limit values*

(c) Industrial hygiene: *Laws and regulations, OSHA : process safety management, risk management, industrial hygiene identification, evaluation and control*

(d) Fire and explosions: *Hazards related to fire and explosions, designs to prevent fires and explosions*

(e) Hazard Identification: *Process hazard check list, hazard surveys, hazard and operability study, other methods*

(f) Risk management and assessment: *Identification, analysis, elimination, financing*

Textbooks:

1. Mackenzie Davis, David Cornwell, *Introduction to Environmental Engineering*, Fifth Edition, McGraw-Hill, 2012 (ISBN-13: 978-0073401140)
2. G Scott, *Polymers and the Environment*, Royal Society of Chemistry, 1999 (ISBN-13: 978-0854045785)
3. Daniel A. Crowl, Joseph F. Louvar, *Chemical Process Safety: Fundamentals with Applications*, Third Edition, Prentice Hall, 2011 (ISBN-13: 978-0131382268)

Reference book:

4. L. Lundquist , Y. Leterrier, P. Sunderland, J.A.E. Manson, *Life Cycle Engineering of Plastics: Technology, Economy and Environment*, Elsevier Science, 2001 (ISBN-13: 978-0080438863)

PPE-301 MECHANICAL PROPERTIES OF POLYMERS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. The mechanical properties of polymers: *General considerations, different types of mechanical behavior, elastic solid and behavior of polymers, stress and strain, state of stress, state of strain, generalized Hooke's law, generalized definition of strain, stress tensor, stress–strain relationships, strain energy functions*
2. Principles of linear viscoelasticity: *Linear viscoelastic behavior, creep, stress relaxation, Boltzmann superposition principle, stress relaxation modulus, mechanical models, retardation and relaxation time spectra, dynamic mechanical measurements: the complex modulus and complex compliance, Alfrey approximation*
3. Measurement of viscoelastic behavior including creep and stress relaxation, dynamic mechanical measurements, wave-propagation methods
4. Experimental studies of linear viscoelastic behavior as a function of frequency and temperature: *Time–temperature equivalence, flexible molecular chain models*
5. Relaxation transitions: *Experimental behavior and molecular interpretation, amorphous polymers, factors affecting the glass transition in amorphous polymers, relaxation transitions in crystalline polymers*
6. Creep, stress relaxation and non-linear viscoelasticity, Eyring equation
7. Yielding and instability in polymers: *Discussion of load–elongation curves in tensile testing, ideal plastic behavior, cold-drawing, molecular interpretations of yield and cold-drawing*
8. Breaking phenomena: *Principles of brittle fracture of polymers, crazing in glassy polymers, impact strength of polymers, fatigue in polymers*

Textbook:

1. Ian M. Ward, John Sweeney, *Mechanical Properties of Solid Polymers*, Third Edition, John Wiley & Sons, Inc., 2013 (ISBN-13: 978-1444319507)

Reference books:

2. L. E. Nielsen, Mechanical Properties of Polymers, Van Nostrand Reinhold, 1962 (ISBN-13: 978-1258246884)
3. G.M. Swallowe, "Mechanical Properties and Testing of Polymers", Springer, 1999
4. F.W Billmeyer, "Textbook of Polymer Science", John Wiley & Sons, 2007

PPE-302 & PPE-302L POLYMER REACTION ENGINEERING

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

SECTION-I INTRODUCTION

Overview of chemical reaction engineering

SECTION-II HOMOGENEOUS REACTIONS IN IDEAL REACTORS

(a) Kinetics of homogeneous reactions: *Concentration-dependent term of a rate equation, temperature-dependent term of a rate equation, searching for a mechanism, predictability of reaction rate from theory*
(b) Interpretation of batch reactor data: *Constant-volume batch reactor, varying-volume batch reactor, temperature and reaction rate, the search for a rate equation*
(c) Introduction to reactor design
(d) Ideal reactors for a single reaction: *Ideal batch reactors, steady-state mixed flow reactors, steady-state plug flow reactors*
(e) Design for single reactions: *Size comparison of single reactors, multiple-reactor systems, recycle reactor, autocatalytic reactions*
(f) Design for parallel reactions
(g) Potpourri of multiple reactions: *Irreversible first-order reactions in series, first-order followed by zero-order reaction, zero-order followed by first-order reaction, successive irreversible reactions of different orders, reversible reactions, irreversible series-parallel reactions, the Denbigh reaction and its special cases*

SECTION-III POLYMER REACTION ENGINEERING

(a) Introduction to polymerization processes: *Polymerization techniques, polymerization reactors*
(b) Coordination polymerization: *polyolefin types: Microstructural classification and analytical techniques, catalysts for olefin polymerization, industrial olefin polymerization reactors*
(c) Free-radical polymerization: Homogeneous systems: *polymer reaction engineering aspects*
(d) Case studies of free-radical polymerization: Heterogeneous systems: *high-impact polystyrene, vinyl chloride monomer bulk polymerization*
(e) Case studies of step-growth polymerization: *Poly(ethylene terephthalate) production, polyamide production processes*

Textbooks:

1. Jose Asua (Editor), *Polymer Reaction Engineering*, Wiley-Blackwell, 2007 (ISBN: 978-1405144421)
2. Octave Levenspiel, *Chemical Reaction Engineering*, Third Edition, Wiley, 1998 (ISBN-13: 978-0471254249)

LABORATORY:

Polymer reaction engineering laboratory would involve experiments performed on a batch, continuous stirred tank reactor, continuous stirred tank reactor in series unit and tubular reactor.

In the second portion of the laboratory polymerization kinetics of the polymers including polyester, polyacrylates and polystyrene would be investigated using using DSC, intrinsic viscosity and rheo-kinetics.

PPE-303 POLYMER COMPOUNDING

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

SECTION-I OVERVIEW

(a) An overview of additives
(b) Types of additive and the main technical trends: *Current lines of development, special additives, multi-functional formulations, masterbatches, dendritic polymers*
(c) The world market: *World consumption of additives, the market for master-batch, overall commercial trends, growth of specialist compounders, regional factors*

SECTION-II MODIFYING SPECIFIC PROPERTIES

(a) Mechanical properties — fillers: *Effect of fillers, factors for compounding, types of fillers, surface modification, nano-technology*
(b) Mechanical properties – reinforcements: *Types of reinforcing fibers*
(c) Appearance - colorants, pigments, dyes, special effects: *Main types of pigment and colorant, dyes, liquid colors, pigments for special effects, thermo-chromic and photochromic pigments, laser marking, pigment dispersants, multi-functional systems, pigments for engineering plastics, the effect of pigments on dimensions, colorants for food and medicals, recent developments, color strength, weathering, natural effects, surface treatment. types of black and white pigments and masterbatches*
(d) Appearance - black and white pigmentation
(e) Resistance to heat – heat stabilizers: *Heat stabilizers, antioxidants, anti-ozonants*
(f) Resistance to light – UV stabilizers
(g) Modifying specific properties: flammability – flame retardants: *Types of flame retardants (halogen, phosphorus, and other halogen free and metal flame retardants), synergistic reactions*
(h) Conductivity - antistatic/conductive additives: *Antistatic agents, conductive additives, ESD (electrostatic discharge) compounds, EMI (electromagnetic interference) compounds, metallic additives, coated polymers, intrinsically conductive material*

SECTION-III MODIFYING PROCESSING CHARACTERISTICS

(a) Curing and crosslinking: *Curing agent, accelerators, inhibitors, curing agent for epoxy, selecting a cure system, UV cure system*
(b) Coupling, compatibilizing agents
(c) Plasticizers: *Types of plasticizers, extender and secondary plasticizer, health and safety of plasticizer, reducing the loading of plasticizer*
(d) Blowing agents: *Physical and chemical blowing agent, structural foam and syntactic structural foam, replacement of CFCs*
(e) Modifiers and processing aids: *Impact modifier, elastomer modifier, processing aids, lubricants, mold release agents, anti-blocking and anti-slip agents, antibacterial and biocides, degradation additives, shrinkage modifier, barrier modifiers, antifogging agents*
(f) Lubricants, mold, release agents, anti-slip and anti-blocking

SECTION-IV OTHER TYPES OF ADDITIVE

(a) Miscellaneous additives
(b) Additives for rubber
(c) Additives for recycling*: stabilizers, properties modifier, melt flow/viscosity modifier, compatibilizers*

SECTION-V COMPOUNDING OF POLYMERS

(a) Pre-compounding operations: *Feeders, pre-blending, pre-conditioning*
(b) Compounder types: *Screw nomenclature and geometry, batch-type compounders, extruders for*

compounding, types of twin-screw extruder

(c) Unit operations for polymer compounding

(d) Case studies for setting up of formulations (PVC, PE, PP, and expendable PS)

SECTION-VI POLYMER BLENDS

(a) Introduction to polymer blending

(b) Equilibrium phase behavior

(c) Compatibilization: *Post-compounding operations, reactive compatibilization*

(d) Preparation and phase structure development: *Methods of blend preparation, phase structure development in molten state, binary polymer blends, blends containing a compatibilizer, structure determination of polymer blends*

(e) Physical properties of polymer blends: *Toughness of polymer blends*

(f) Commercially important polymer blends

Textbooks:

1. John Murphy, *Additives for Plastics Handbook*, Second Edition Elsevier, 2001 (ISBN-13: 978-1856173704)
2. Robert H. Wildi, Christian Maier, *Understanding Compounding*, Hanser Gardner, 1998 (ISBN-13: 978-1569902288)

Reference book:

3. Herman F. Mark, Polymer Blends in *Encyclopedia of Polymer Science and Technology*, Third Edition, Wiley-Interscience, 2004 (ISBN-13: 978-0471275077)

PPE-304 & PPE-304L SIMULATION IN POLYMER PROCESSING

Credit Hours: 3 (Theory = 2, Laboratory = 1), Contact Hours: 5 (Theory = 2, Laboratory = 3)

SECTION-I INTRODUCTION TO SIMULATION IN POLYMER PROCESSING

1. Introduction to computer-aided drafting (CAD), computer-aided manufacturing (CAM) and term computer-aided engineering (CAE)
2. Simulation and polymer processing: *Extrusion, blown film extrusion, blow molding, vacuum forming, injection molding and its variants*
3. History of injection-molding simulation
4. Current technology for injection-molding simulation
5. Machine control
6. Introduction to the software programs used in the simulation of polymer processing operations
7. The concept of finite element analysis (FEM)
8. Future of simulation in polymer processing

SECTION-II FACTORS AFFECTING INJECTION MOLDING

1. Polymer flow behavior in injection molds: *Phases of injection molding, flow behavior of plastics*
2. Molding conditions and injection pressure*: Injection-pressure overview, factors influencing injection-pressure requirements, channel flow equations, effect of molding conditions*
3. Filling pattern: *Filling pattern overview, flow in complex molds, flow-front velocity and flow-front area, using injection molding simulation (IMS) to determine the filling pattern*
4. Design principles: *Product design and IMS, sequence of analysis, IMS flow concepts*
5. Gate design: *Gate design overview, gate types, design rules, using IMS for gate design*

6. Runner system design: *Runner system overview, runner system design principles, runner types, runner layout, initial runner sizing, runner balancing*
7. Cooling system design: *Mold cooling system overview, cooling-channel configuration, alternative cooling devices, cooling system equations, design rules*
8. Shrinkage and warpage: *Injection molding and shrinkage, basic causes of shrinkage and warpage, designing accurate parts considering warpage*

SECTION-III OPTIMIZATION OF INJECTION MOLDING PROCESS USING IMS SOFTWARE

1. Design of experiments using Taguchi's experimental design
2. Analysis of variance
3. Case studies: *Case-studies to optimize various aspects of injection molding simulation using experimental design including optimization of process parameters, cooling optimization, reduction of sink marks and warpage*

SECTION-IV SIMULTAION IN EXTRUSION TECHNOLOGY

1. Use of simulation software to study the various aspects of polymer extrusion process

Textbook:

1. Jay Shoemaker (Editor), *Moldflow Design Guide: A Resource for Plastics Engineers*, Hanser Publications, 2006 (ISBN-13: 978-1569904039)

Reference books:

2. Charles A. Harper, *Modern Plastics Handbook*, McGraw-Hill Professional, 2000 (ISBN-13: 978-0070267145)
3. Dominick V. Rosato, Donald V. Rosato, *Plastics Engineered Product Design*, Elsevier Science, 2003 (ISBN-13: 978-0444560490)

LABORATORY:

The laboratory section involves simulations of various aspects of polymer processing e.g. injection molding using commercial software packages (SolidWorks Plastics, Moldflow), under the supervision of an instructor.

PPE-305 POLYMER THERMODYNAMICS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. Vapor/liquid equilibrium: *The nature of equilibrium, the phase rule: Duhem's theorem, VLE: qualitative behavior, simple models for vapor/liquid equilibrium, VLE by modified Raoult's Law, VLE from K-value correlations*
2. Theory of solution thermodynamics: *Fundamental property relation, the chemical potential and phase equilibria, partial properties, ideal-gas mixtures, fugacity and fugacity coefficient: pure species, fugacity and fugacity coefficient: species in solution, generalized correlations for the fugacity coefficient, the ideal solution, excess properties*
3. Applications of solution thermodynamics: *Liquid-phase properties from VLE data, models for the excess Gibbs energy, property changes of mixing, heat effects of mixing processes*
4. Polymer solubility and solutions: *General rules for polymer solubility, typical phase behavior in polymer–solvent systems, the thermodynamic basis of polymer solubility, the solubility parameter, the Flory–Huggins theory, properties of dilute solutions, polymer–polymer-common solvent systems, polymer solutions, suspensions, and emulsions, concentrated solutions: plasticizers*, *pure polymer PVT behavior, modelling approaches to polymer solution thermodynamics, lattice models, Lichtemthaler's and Wilson's modifications, Sanchez-Lacombe equation of state, Panayiotou-Vera equation of state, Kumar equation of state, High-Danner equation of state, Oishi-Prausnitz activity coefficient model, Van Der Waals Models, Flory equation of state, Rasmussen equation of state, liquid-liquid equilibria of polymer Solutions and copolymers, effect of polydispersity*

Textbook:

1. J. M. Smith, Hendrick Van Ness, Michael Abbott, *Introduction to Chemical Engineering Thermodynamics*, Seventh Edition, McGraw-Hil, 2004 (ISBN-13: 978-0073104454)
2. Ronald P. Danner, Martin S. High, *Handbook of Polymer Solution Thermodynamics*, Wiley-AIChE, 1993 (ISBN-13: 978-0816905799)
3. Christopher S. Brazel, Stephen L. Rosen, *Fundamental Principles of Polymeric Materials*, Third Edition, John Wiley & Sons, Inc., 2012 (ISBN-13: 978-0470505427)

Reference book:

4. Menno A. van Dijk, Andre Wakker, Concepts in Polymer Thermodynamics, CRC Press, 1998 (ISBN-13: 978-1566766234)

PPE-306 & PPE-306L POLYMER ANALYSIS & CHARACTERIZATION

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

Part-I SPECTROSCOPY

(a) Fourier transform infrared spectroscopy (FTIR) spectroscopy
(b) UV spectroscopy
(c) Introductory level Raman spectroscopy, energy dispersive X-ray spectroscopy (EDS), mass spectroscopy, Nuclear magnetic resonance spectroscopy (NMR), atomic absorption spectroscopy (AAS)

Part-II THERMAL AND THERMOMECHANICAL ANALYSIS

(a) Differential scanning calorimetry (DSC)
(b) Thermogravimetric analysis (TGA)
(c) Dynamic mechanical analyzer (DMA)
(d) Thermo-mechanical analyzer (TMA)

Part-III CHRMOMATOGRAPHY
(a) Size exclusion chromatography (SEC) with emphasis on gel permeation chromatography (GPC)
(b) High performance liquid chromatography (HPLC)
(c) Gas chromatography (GC)

Part-IV RHEOMETRY
(a) Torque rheometers
(b) Rotational rheometers and viscometers
(c) Capillary rheometer

Part-V MICROSCOPY
(a) Optical microscopy
(b) Electron microscopy including transmission electron microscope (TEM) and scanning electron microscope (SEM)
(c) Scanning probe microscopy
(d) Atomic force microscopy

Part-VI ELECTROCHEMICAL CHARACTERIZATION
(a) Open circuit voltammetry
(b) Cyclic voltammetry
(c) Linear polarization
(d) Electrochemical impedance spectroscopy (EIS)

Textbooks:
1. Wiley, *Characterization and Analysis of Polymers*, Wiley-Interscience, 2008 (ISBN-13: 978-0470233009)
2. Alberto Naranjo, María del Pilar Noriega E., Tim A. Osswald, Alejandro Roldán-Alzate, Juan Diego Sierra, *Plastic Testing and Characterization: Industrial Applications*, Carl Hanser Verlag, Munich, 2008 (ISBN-13: 978-1569904251)

Reference books:
3. Hubert Lobo (Editor), Jose V. Bonilla (Editor), *Handbook of Plastics Analysis*, CRC Press, 2003 (ISBN-13: 978-0824707088)
4. Joseph D. Menczel (Editor), R. Bruce Prime (Editor), *Thermal Analysis of Polymers: Fundamentals and Applications*, Wiley, 2009 (ISBN-13: 978-0471769170)

LABORATORY:
The laboratory section involves the experimentation on the polymer characterization equipment including FTIR, DMA, DSC, TGA, UV spectrophotometry, potnetiostat, under the supervision of an instructor.

PPE-307 TRANSPORT PHENOMENA

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

SECTION I MOMENTUM TRANSPORT

(a) Viscosity and the mechanisms of momentum transport: *Newton's law of viscosity, generalized Newton's law of viscosity, pressure and temperature dependence of viscosity, molecular theory of viscosity of gas at low density, molecular theory of viscosity of emulsions, convective momentum transport*

(b) Shell momentum balances and velocity distributions in laminar flow: *Shell momentum balance and boundary conditions, flow of a falling film, flow through a circular tube, flow through annulus, flow through adjacent immiscible fluids, creeping flow around a sphere*

(c) The equations of change for isothermal systems: *The equation of continuity, the equation of motion, the equation of mechanical energy, the equation of angular momentum*

SECTION II ENERGY TRANSPORT

(a) Thermal conductivity and the mechanisms of energy transport: *Fourier's law of heat conduction, temperature and pressure dependence of heat conductivity, theory of thermal conductivity of gases at low density, theory of thermal conductivity of liquids, thermal conductivity of solids, effective thermal conductivity of composite solids, convective transport of energy*

(b) Shell energy balances and temperature distributions in solids and laminar flow: *Shell energy balance boundary conditions, heat conduction with a chemical heat source, heat conduction through a composite wall*

SECTION III MASS TRANSPORT

(a) Diffusivity and the mechanisms of mass transport: *Fick's law of binary diffusion, temperature and pressure dependence of diffusivities, theory of diffusivity of gases at low density, theory of diffusion in binary liquids, theory of diffusion in colloidal suspensions, theory of diffusion of polymers, mass and molar transport by convection, the Maxwell-Stefan equations for multicomponent diffusion in gases at low density*

Textbook:

1. R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot, *Transport Phenomena*, Second Edition, John Wiley & Sons, Inc., 2006 (ISBN-13: 978-0470115398)

PPE-308 & PPE-308L POLYMER PROCESSING DESIGN

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

Part-I POLYMER PROCESSES

(a) Extrusion: *The plasticating extruder, extrusion dies*

(b) Mixing processes: *Distributive mixing, dispersive mixing, mixing devices*

(c) Injection molding: *The injection molding cycle, the injection molding machine, related injection molding processes*

(d) Secondary shaping: *Fiber spinning, film production, thermoforming*

(e) Calendering

(f) Coating

(g) Compression molding

(h) Foaming

(i) Rotational molding

Part-II TRANSPORT PHENOMENA IN POLYMER PROCESSING

(a) Single dimensional analysis and scaling: *Dimensional analysis, dimensional analysis by matrix transformation, problems with non-linear material properties, scaling and similarity*
(b) Balance equations
(c) Model simplification: *Reduction in dimensionality, lubrication approximation*
(d) Simple Models in Polymer Processing*: Pressure driven flow of a Newtonian fluid through a slit, flow of a power law fluid in a straight circular tube (Hagen-Poiseuille equation), flow of a power law fluid in a slightly tapered tube, volumetric flow rate of a power law fluid in axial annular flow, radial flow between two parallel discs − Newtonian model, the Hele-Shaw model, cooling or heating in polymer processing*

Part-III POLYMER PROCESSING DESIGN

(a) Single screw extrusion−isothermal flow problems: *Newtonian flow in the metering section of a single screw extruder, cross channel flow in a single screw extruder, Newtonian isothermal screw and die characteristic curves*
(b) Extrusion dies−isothermal flow problems: *End-fed sheeting die: coat hanger die, extrusion die with variable die land thicknesses, pressure flow of two immiscible fluids with different viscosities, fiber, spinning, viscoelastic fiber spinning model*
(c) Processes that involve membrane stretching: *Film blowing, thermoforming*
(d) Coating processes*: Wire coating die, roll coating*
(e) Injection molding − isothermal flow problems: *Balancing the runner system in multi-cavity injection molds, radial flow between two parallel discs*
(f) Melting and solidification: *Melting with pressure flow melt removal, melting with drag flow melt removal, melting zone in a plasticating single screw extruder*
(g) Mixing − isothermal flow problems: *Effect of orientation on distributive mixing − Erwin's ideal mixer, predicting the striation thickness in a Couette flow system – shear thinning model, residence time, distribution of a fluid inside a tube, residence time distribution inside the ideal mixer*
(h) Curing reactions during processing

Textbook:

1. Tim A. Osswald, Juan P. Hernández-Ortiz, *Polymer Processing: Modeling and Simulation*, Hanser, 2006 (ISBN-13: 978-1569903988)

Reference books:

2. Zehev Tadmor, Costas G. Gogos, *Principles of Polymer Processing*, Second Edition, Wiley-Interscience, 2006 (ISBN-13: 978-0471387701)
3. Donald G. Baird, Dimitris I. Collias, *Polymer Processing: Principles and Design*, Second Edition, Wiley, 2014 (ISBN-13: 978-0470930588)

LABORATORY:

Polymer processing design laboratory would involve experiments performed on blown film extrusion plant, injection molding machine, recycle extruder, pipe manufacturing plant, wire coating plant and rubber extrusion unit.

PPE-309 & PPE-309L PROCESS ENGINEERING COMPUTING

Credit Hours: 3 (Theory = 2, Laboratory = 1), Contact Hours: 5 (Theory = 2, Laboratory = 3)

SECTION-I BASICS OF PROCESS ENGINEERING COMPUTING

(a) Significance of process engineering computing
(b) Introduction to computing software including Microsoft Excel and MATLAB

SECTION-II APPLICATIONS OF PROCESS ENGINEERING COMPUTING

(a) Equations of state: *Equations of state—mathematical formulation, solving equations of state using Excel and MATLAB*
(b) Vapor–liquid equilibria: *Flash and phase separation, isothermal flash—development of equations using excel, thermodynamic parameters*
(c) Chemical reaction equilibria: *Chemical equilibrium expression, example of hydrogen for fuel cells, chemical reaction equilibria with two or more equations*
(d) Mass balances with recycle streams: *Example without recycle, example with recycle; comparison of sequential and simultaneous solution methods, example of process simulation using Excel for simple mass balances, example of process simulation with Excel including chemical reaction equilibria*
(e) Chemical reactors: *mathematical formulation of reactor problems, plug flow reactor and batch reactor, continuous stirred tank reactor, using MATLAB to solve ordinary differential equations, continuous stirred tank reactors with Excel and MATLAB, transient continuous stirred tank reactors using MATLAB*
(f) Transport processes in one dimension: *Applications in chemical engineering—mathematical formulations, heat transfer in a slab using MATLAB, transient heat transfer using MATLAB*
(g) Fluid flow in two and three dimensions using MATLAB
(h) Heat and mass transfer in two and three dimensions using MATLAB

Textbook:

1. Bruce A. Finlayson, *Introduction to Chemical Engineering Computing*, Second Edition, Wiley, 2014 (ISBN-13: 978-1118888315)

Reference books:

2. Richard G. Rice, Duong D. Do, *Applied Mathematics And Modeling For Chemical Engineers*, Second Edition, Wiley-AIChE, 2012 (ISBN-13: 978-1118024720)
3. Amiya K. Jana, *Chemical Process Modelling and Computer Simulation*, PHI, Second Edition, 2011 (ASIN: B00K7YGZMG)

LABORATORY:

In the laboratory section of the subject the students will be required to solve various problems related to polymer and process engineering using mathematical software packages like Excel and Matlab.

PPE-310 & PPE-310L INSTRUMENTATION AND CONTROL

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

SECTION I CONTROL SYSTEM INTRODUCTION

(a) Incentives for chemical process control
(b) Design aspects of a process control system: *Classification of variables in a chemical process, design element of a control system, control aspects of a complete chemical plant*
(c) Hardware for a process control system: *Hardware elements of a control system*

SECTION II MODELLING A CONTROL SYSTEM

(a) Modelling the dynamic and static behavior of chemical processes: *The need of a mathematical model for a process control, elements of mathematical model. modelling difficulties*
(b) The input-output models

SECTION III LAPLACE TRANSFORM

(a) Review of Laplace transform: *Laplace transform of basic functions, integrals, derivatives, final value theorem, initial value theorem, linearization, inversion of Laplace transform*

SECTION IV TRANSFER FUNCTION OF PROCESS SYSTEMS

(a) Transfer function of a process with single output, with multiple outputs, qualitative analysis of the response of a system
(b) Dynamic behavior of first-, second- and higher-order systems and their dynamics: *Introduction, processes modelled as first, second and nth order system, dynamic response of pure capacitive system, dynamic response of first order lag system, multi-capacity processes as second order systems, inherently second order processes, second order system caused by the presence of controllers, dynamic system with dead time, dynamic systems with inverse response, overall transfer function testability; introduction of frequency response techniques*

SECTION V TRANSFER FUNCTION OF PROCESS SYSTEMS

(a) Introduction to feedback control: *Concept of feedback control, types of feedback controllers, measuring devices, transmission lines, final control elements*
(b) Dynamic behavior of feedback controlled processes: *Block diagram and the closed-loop response, effect of proportional control on the response of a controlled process, effect of integral control action, effect of derivative control action, effect of composite control actions*
(c) Stability analysis of feedback systems: *Notion of stability, the characteristic equation, Routh-Hurwitz criterion for stability, Roor-Locus analysis*

SECTION VI CONTROLLER TYPES AND INSTRUMENTS

(a) Theoretical and practical controllers
(b) Final control elements
(c) Process control using computers
(d) Measuring instruments for temperature, pressure, and level
(e) Control of heat exchangers and distillation columns
(f) Control of polymerization reactors

Textbook:

1. George Stephanopoulos, *Chemical Process Control: An Introduction to Theory and Practice,* PTR Prentice Hall, 1984, ISBN-13: 978-0131286290

Reference book:

2. Jose Asua (Editor), *Polymer Reaction Engineering*, Wiley-Blackwell, 2007 (ISBN: 978-1405144421)

LABORATORY:

In instrumentation and control laboratory, students would perform experiments on different experimental rigs (pH process rig, temperature process rig, basic process rig etc.) and calibrators (dead weight calibrators, thermocouple calibrator etc.) to get an idea of how to control and calibrate various instrumentation applied in a process plant.

PPE-401 POLYMER RHEOLOGY

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. Introduction to rheology: *Polymers and the importance of rheology, rheology in its simplest form, types of fluids, application to processing*
2. Stress, strain, velocity and rate of deformation: *Stress and pressure, stress tensor, velocity gradients, rate of deformation tensor, continuity equation*
3. Continuum mechanics: *Concept of continuum, various time derivatives, equation of motion*
4. Newtonian and Generalized Newtonian Fluids (GNF): *Definition of Newtonian behavior, need of GNF, generalized GNF for 3D, inventing GNF relationship and parameters from data*
5. Normal stresses: *Types and origin of normal stresses, the second normal stress difference, normal-stress coefficients and empirical findings, transient rheological functions, temperature effects and superposition of steady-flow data*
6. Analysis of simple flow: *Poiseuille flow, drag flow*
7. Experimental methods of rheological characterization: *Measurement of viscosity, normal stresses from shearing flows, extensional rheology, specialized geometries, flow visualization and other rheo-optical methods, micro and nano rheology, velocity-profile correction for non-Newtonian fluids, the Mooney correction*
8. Elementary polymer processing concepts: *Simple laboratory processing methods, elementary extrusion concepts, a downstream process—spinning*
9. Rheology and molecular structure: *Introduction and qualitative overview of molecular theory, molecular weight dependence of zero shear viscosity, compliance and first normal stress difference, shear rate dependence of viscosity, temperature and pressure dependence, effects of long chain branching*
10. Solution rheology: *Polymer chain conformation, zero-shear viscosity*

Textbook:

1. Montgomery T. Shaw, *Introduction to Polymer Rheology*, Wiley, 2012 (ISBN-13: 978-0470388440)

Reference books:

2. John M Dealy, Jian Wang, *Melt Rheology and its Applications in the Plastics Industry*, Second Edition, Springer, 2013 (ASIN: B00CRU9KMK)
3. Joel R. Fried, *Polymer Science and Technology*, Third Edition, Prentice Hall, 2014 (ISBN-13: 978-0137039555)

PPE-402 POLYMER PRODUCT DESIGN

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. Introduction to product design: *Advantages and disadvantages of plastics, sources of technical information and standards, the holistic design approach with example*
2. Overview of mechanical, thermal and optical properties of polymers: *Effects of molecular weight on plastics properties, characterization using thermal analysis tests, short-term mechanical properties and their dependence on various factors, viscoelasticity and superposition, dynamic properties, fracture mechanics and impact behavior, hardness and abrasion resistance*
3. Material selection, process selection and product design: *General criteria for materials selection, comparative properties of various families of thermoplastics and thermosets, product design guidelines and details for various processes, cost estimation*
4. Product design and processing characteristics for:
    (a) Extrusion: *The screw theory, extrusion zones, sheet, oriented flat sheet, blown film, fiber and rubber extrusion, design of profile dies*
    (b) Injection molding: *Cycle of operation, IM machine rating, mold design, filling, orientation and shrinkage studies*
    (c) Blow molding: *Extrusion and injection blow molding, stretch blow molding, part and parison thickness relationship, mold details*
    (d) Thermoforming
    (e) Compression molding: *BMC, SMC, prepregs, long fiber*
    (f) Foams and foaming processes: *Uses of foam and foaming processes, EPS, RIM foam molding, Integral foam molding and design*
5. Designing mechanical components in plastics: *Plastic pipes and tubing, gears and bearings*
6. Computer aided design (CAD): *Geometric modeling, design accuracy, design software, finite element analysis (FEA)*
7. Design reliability: *Testing and QC, product failure, meaning of data, safety factors*

Textbooks:

1. Harold Belofsky, *Plastics: Product Design and Process Engineering*, Hanser, 1995 (ISBN-13: 978-3446181557)
2. Charles A. Harper, *Modern Plastics Handbook*, McGraw-Hill Professional, 2000 (ISBN-13: 978-0070267145)

Reference book:

3. Dominick V. Rosato, Donald V. Rosato, *Plastics Engineered Product Design*, Elsevier Science, 2003 (ISBN-13: 978-0444560490)

PPE-403 & PPE-403L PROCESS PLANT DESIGN

Credit Hours: 4 (Theory = 3, Laboratory = 1), Contact Hours: 6 (Theory = 3, Laboratory = 3)

1. Introduction: *Chemical engineering plant design, general overall design considerations, practical considerations in design, engineering ethics in design*
2. General design considerations: *Health and safety hazards, loss prevention, environmental protection, plant location, plant layout, plant operation and control*
3. Process design development: *Development of design database, process creation, process design, process flow diagrams, piping and instrumentation diagrams, equipment design and specifications, the preliminary design*
4. Flowsheet synthesis and development: *Flowsheet synthesis and development, process information, input/output structure, functions diagram, operations diagram, process flowsheet, software use in flowsheet synthesis*
5. Optimum design and design strategy: *Defining the optimization problem, selecting an objective function, sub-optimization, programming optimization problems, optimization solution methodologies, optimization applications*
6. Materials and fabrication selection: *Factors contributing to corrosion, combating corrosion, properties of materials, tabulated data for selecting materials of construction, selection of materials, fabrication of equipment*
7. Materials-handling equipment—design and costs: *Basic concepts of fluid transport, piping in fluid transport processes, pumping of fluids, compression and expansion of fluids, agitation and mixing of fluids, flow measurement of fluids, storage and containment of fluids, transport of solids, handling of solids*
8. Reactor equipment—design and costs: *Reactor principles, development of chemical reaction rate expressions, reaction and reactor performance, reactor and catalyst equipment*
9. Heat-transfer equipment—design and costs: *Basic theory of heat transfer in exchangers, determination of heat-transfer coefficients, determination of pressure drop in heat exchangers, selection of heat exchanger type, design of key heat exchanger types, optimum design of heat exchangers, general methods for design of heat exchangers*
10. Separation equipment—design and costs**:** *Selection of suitable separation processes, equipment design and costs for separating homogeneous mixtures, separation by distillation, separation by absorption and stripping, separation by extraction, separation using membranes, separation by adsorption, equipment design and costs for separating heterogeneous mixtures, separation by drying, separation by filtration*

Textbook:

1. Max Peters, Klaus Timmerhaus, Ronald West, *Plant Design and Economics for Chemical Engineers*, Fifth Edition, McGraw-Hill, 2002 (ISBN-13: 978-0072392661)

Reference book:

2. Gavin Towler, R K Sinnott, *Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design*, Second Edition, Butterworth-Heinemann, 2012 (ISBN-13: 978-0080966595)

LABORATORY:

In the process plant design laboratory students will use HYSYS software to carry out plant design calculations and tutorials.

PPE-404L PLANT DESIGN PRACTICE

Credit Hours: 3 (Laboratory = 1), Contact Hours: 9 (Laboratory = 3)

Students (Groups of 4 to 5) are assigned various plant design projects under the supervision of faculty members. The projects involve comprehensive design of a process plant. The students are required to perform materials and energy balances on a process flow sheet, design various equipment, perform economic and safety analysis of the plant and report the findings in the form of a report.

PPE-405 FINAL YEAR PROJECT-I

Credit Hours: 3
Contact Hours: 9

Students (Groups of 4 to 5) are assigned various projects under the supervision of faculty members. The projects are related to latest research on-going in the field of polymer engineering. The projects are floated by the faculty members at the start of the session.

PPE-406 FINAL YEAR PROJECT-II

Credit Hours: 3
Contact Hours: 9

Students (Groups of 4 to 5) are expected to write a compressive thesis of the work carried out in “Polymer Research-I”. The Final Year Project (FYP) involves evaluation by academic and industrials experts.

DEPARTMENT ELECTIVES

PPE-407 POLYMER COMPOSITES

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. Introduction: *Definition, general characteristics, applications, material selection process*
2. Materials, fibers, thermoset & thermoplastic matrices, fiber surface treatments, fillers and other additives, incorporation of fibers into matrix, prepregs, sheet-molding compounds, incorporation of fibers into thermoplastic resins, fiber content, density, and void content, fiber architecture
3. Manufacturing: *Fundamentals, bag-molding process, compression molding, pultrusion, filament winding, liquid composite molding process, other manufacturing processes, manufacturing processes for thermoplastic matrix composites, quality inspection methods*
4. Mechanics: *Fiber–matrix interactions in a unidirectional lamina, characteristics of a fiber-reinforced lamina, laminated structure, elastic deformation of laminates, stresses and distortions*
5. Performance, multiply laminates, balanced and symmetric laminates, cross-ply laminates, multidirectional laminates, woven fabric laminates, sheet-molding compounds, interply hybrid laminates, compressive properties, flexural properties, in-plane shear properties, interlaminar shear strength, the interface region, bonding mechanisms, experimental measurements of bond strength at fiber/ matrix interphase, control of bond strength
6. Strength of composites: *Failure modes of long fiber composites, failure of laminates under off axis load, strength of laminates, composite failure criteria, maximum stress criteria, maximum strain criteria, Tsai hill criteria, Tsai-Wu criteria, Hashin criteria, Puck's criteria, fracture mechanics of composite materials*
7. Polymer nanocomposites: *Nanoclay, carbon nanofibers, carbon nanotubes, structure, production of carbon nanotubes, functionalization of carbon nanotubes, mechanical properties of carbon nanotubes, carbon nanotube–polymer composites, properties of carbon nanotube–polymer composites*
8. Recycling of polymer composites material selection
9. Latest research trends in polymer composites

Text books

1. D. Hull & T.W. Clyne, *An Introduction to Composite Materials*, 2nd Ed., Cambridge University Press, 1997
2. P.K. Mallick, *Fiber reinforced composites: Materials, Manufacturing, and Design*, 3rd Ed., CRC Press, 2007

PPE-408 SMART POLYMERS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

SECTION-I INTRODUCTION AND TYPES OF SMART POLYMER

(a) Introduction to smart polymers and their applications: *Types of smart polymer, applications of smart polymers*
(b) Intrinsically conducting polymers (ICPs)
(c) Temperature-responsive polymers: *Basic principles of temperature-responsive polymers in aqueous solution, Key types of temperature-responsive polymers in aqueous solution, selected applications of thermo-responsive polymers*
(d) pH-responsive polymers: *Key types and properties of pH-responsive polymers, synthesis of pH-responsive polymers, applications*
(e) Photo-responsive polymers: *Chromophores and their light-induced molecular response, Key types and properties of photo-responsive polymers, applications*
(f) Magnetically responsive polymer gels and elastomers: *Preparation of magnetically responsive polymer gels and elastomeric materials, magnetic properties of filler-loaded polymers, Elastic behavior of magnetic gels and elastomers*
(g) Enzyme-responsive polymers: *Key types and properties of enzyme-responsive polymers, preparation of enzyme-responsive polymers, Characterization of enzyme-responsive polymers, applications*
(h) Shape memory polymers: *Characterizing shape memory effects in polymeric materials, classifying shape memory polymers, main applications*
(i) Self-healing polymer systems: *Types of self-healing, self-healing and recovery of functionality in materials, applications*

SECTION-II APPLICATIONS OF SMART POLYMER

(a) Smart instructive polymer substrates for tissue engineering
(b) The use of smart polymers in medical devices for minimally invasive surgery, diagnosis and other applications
(c) Smart polymers for bio-separation and other biotechnology applications
(d) Smart polymers for textile applications
(e) Biopolymers for food packaging applications
(f) Smart polymers for optical data storage

Textbook:

1. Maria Rosa Aguilar and Julio San Roman, *Smart Polymer and their Applications*, Woodhead Publishing, 2014 (ISBN-13: 978-0857096951)

Reference book:

2. Liming Dai, *Intelligent Macromolecules for Smart Devices: From Materials Synthesis to Device Applications*, Springer, 2004 (ISBN-13: 978-1852335106)

PPE-409 ELASTOMERIC MATERIALS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

SECTION I TYPES OF ELASTOMERS

(a) Natural rubber: *Introduction, natural rubber, production of natural rubber, grades of natural rubber, special purpose natural rubber, application of natural rubber*

(b) General and special purpose elastomers: *Styrene butadiene rubber (SBR), polybutadiene rubber (BR), polyisoprene (IR)*

(c) Specialty elastomers: *Polychloroprene (CR), acrylonitrile butadiene rubber (NBR), butyl rubber (IIR), ethylene propylene rubber (EPM, EPDM), silicone rubber (MQ), polysufide rubber, chlorosulphonated polyethylene (CSM), acrylic rubber (ACM), florocarbon rubber (FKM), urethane rubber*

SECTION II COMPOUNDING

(a) Fillers for rubber: *Carbon black, and silica*

(b) General compounding and vulcanization: *Curing agent, accelerators, activators, anti-degradants, antioxidants, anti-ozonants, waxes, processing aids, homogenizers, tackifiers, peptizers, lubricants, plasticizers, resins, retarders, blowing agent*

SECTION III THERMOPLASTIC ELASTOMERS (TPEs)

(a) Introduction, application overview, segmental block copolymers TPEs, thermoplastic polyurethane, styrenic block copolymer, thermoplastic vulcanizates

Textbook:

1. Brendan Rodger, *Rubber Compounding Chemistry and Application*, Marcel Dekker Inc., 2004 (ISBN 0-8247-4871-9)

PPE-410 POLYMERS IN ENERGY APPLICATIONS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. General introduction: Polymers as key components for energy challenges
2. Nanomaterials and nanofluids for energy applications
3. Electrically conductive polymers
4. Ionically conducting polymers
5. Piezoelectric, dielectric, and ferroelectric materials
6. Thermoelectricity
7. Polymers for photovoltaic cells and wind energy
8. Polymers as fuel cells components
9. Biomass energy and polymers
10. Polymers for nuclear energy
11. Polymers for batteries and super-capacitors
12. Polymers in hydrogen-based energy
13. Polymers in cables
14. Energy saving in buildings

Textbook:

1. Vikas Mittal (Editor), *Polymers for Energy Storage and Conversion*, Wiley-Scrivener, 2013 (ISBN-13: 978-1118344545)

Reference book:

2. Martin Moeller (Editor), Krzysztof Matyjaszewski (Editor), *Polymer Science: A Comprehensive Reference, Volume 10, Section: Polymers in Energy Applications*, Elsevier Science, 2012 (ISBN-13: 978-0444533494)

PPE-411 BIO-POLYMERS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

1. Detailed knowledge of the structure, function, and properties of biopolymers: *Structure-property relationships in biological materials, biological materials: scale, heterogeneity, representative volume elements, fibers: the key building blocks for performance and versatility, design and function of structural biological materials, design for stiffness and design for strength*.
2. Case study of some biological materials:
   (a) Proteins: *Amino acids and their polymerization, primary structure, conformation secondary structure, structural proteins, coping with strain energy*
   (b) Sugars and fillers: *Fibers, structural polysaccharides in plants water, the invisible support, mucus*
   (c) Bone: *Composition of bon, integration and organization levels, mechanical properties of the cortical of bone*
   (d) Soft tissue engineering**:** *Structure-properties of soft tissues. articular cartilage, structure and composition, bio-mechanics of articular cartilage, cell seeded repair systems, bio-artificial implants: design and tissue engineering*
   (e) Silk fibers: *Origins, nature and consequences of structure, mechanical properties of spider silks, hierarchical microstructure of silk fibers, spinning - the origins of silk fiber microstructure*
3. Introduction to biomedical materials and bio-mimicking with smart polymers: *Biological ceramics calcium salts or silica, problems with mechanical tests, the functional design of bone, teeth, eggshell, echinoderms, implementing ideas gleaned from biology biomimetic products, quasi-biomimetic products, techniques for bio-mimetics*
4. Synthetic biopolymers: *Poly(alpha-esters) etc, Structure, composition and processing*
5. Environmental issues when using biopolymers and synthetic polymers, the use of biopolymers like sugar based, cellulose based, starch based biopolymers in different application areas e.g. textile, food packaging etc

Textbooks:

1. J. Vincent, *Structural Biomaterials,* Third Edition, 2012 (ISBN: 978-1-4008-4278-0)
2. M. Elices, *Structural Biological Materials*, Vol.4, 2000 (ISBN-13: 978-0444552389)

Reference books:

3. Kumbar & Laurencin and Deng, *Natural and Synthetic Biomedical Polymers,* First Edition, 2014 (ISBN 9780123969835)
4. Susheel Kalia, Luc Avérous, *Biopolymers: Biomedical and Environmental Applications,* 2011 (ISBN: 978-0-470-63923-8)

PPE-412 NANO-MATERIALS

Credit Hours: 3 (Theory = 3), Contact Hours: 3 (Theory = 3)

SECTION-I INTRODUCTION

(a) Introduction
(b) Historical perspective and classification of nanomaterials
(c) Present and future applications of nanotechnology
(d) Classification of nanoparticles

SECTION-II NANOPARTICLE SYNTHESIS

(a) Solid-state synthesis of nanoparticles
(b) Vapor-phase synthesis of nanoparticles
(c) Inert gas condensation of nanoparticles
(d) Plasma-based synthesis of nanoparticles
(e) Flame-based synthesis of nanoparticles
(f) Spray pyrolysis of nanoparticles
(g) Solution processing of nanoparticles
(h) Sol-gel processing
(i) Solution precipitation
(j) Water–oil microemulsion (reverse micelle) method
(k) Commercial production and use of nanoparticles

SECTION-III FULLERENES

(a) Introduction to fullerenes
(b) Structure and properties
(c) Applications

SECTION-IV CARBON NANOTUBES (CNTs)

(a) Chemistry of carbon nanotubes
(b) Nanotubes in multifunctional polymer nanocomposites
(c) CNT-polymer composites

SECTION-V SELECTED APPLIATIONS

(a) Nanomterials for catalysis
(b) Nanoreactors
(c) Nanotechnology and biomaterials
(d) Nanoparticles for drug delivery
(e) Advanced applications of nano-materials

Textbook:

1. Gogotsi, Y. 2006. Nanomaterials Handbook, Taylor & Francis Group, LLC Nanoparticles and Catalysis

Reference books:

2. Zhou, B., Han, S., Raja, R., Somorjai, G.A., 2007. Nanotechnology in Catalysis, Vol.3, Springer Science and Business Media, LLC
3. Klabunde, K. J. 2001. Nanoscale Materials in Chemistry, Wiley Inter-science, John Wiley & Sons, Inc., New York

EXAMPLE (CONDENSED)

Rules: 1st and 2nd Year (18 CR not exceeding 26 CtH), 3rd and 4th year (20 CR not exceeding 30 CtH)

FALL		SPRING		SUMMER
PPE-101	3(3,0)	PPE-102 & PPE-102L	4(3,1)	
PPE-103 & PPE-103L	4(3,1)	PPE-104 & PPE-104L	3(2,1)	
CS-101	3(2,1)	PPE-106 & PPE-106L	4(3,1)	
CY-161	3(2,1)	MA-118	3(3,0)	Optional
MA-113	3(3,0)	HU-111L	1(0,1)	
	16(22)	IS-101	3(3,0)	
			18(26)	
PPE-201 & PPE-201L	4(3,1)	PPE-105	3(3,0)	
PPE-202	3(3,0)	PPE-205 & PPE-205L	4(3,1)	
PPE-203	3(3,0)	PPE-206	3(3,0)	
PPE-204 & PPE-204L	4(3,1)	PPE-302 & PPE-302L	4(3,1)	Optional
IS-201	3(3,0)	HU-221	3(3,0)	
ME 100L	1(0,1)			
	18(24)		**17(21)**	
PPE-301	3(3,0)	PPE-303	3(3,0)	
PPE-305	3(3,0)	PPE-304 & PPE-304L	3(2,1)	
PPE-307	3(3,0)	PPE-306 & PPE-306L	4(3,1)	
PPE-309 & PPE-309L	3(2,1)	PPE-308 & PPE-308L	4(3,1)	Optional
PPE-311	3(3,0)	PPE-310 & PPE-310L	4(3,1)	
MA-346	3(2,1)			
	18(23)		**18(22)**	
PPE-401	3(3,0)	PPE-402	3(3,0)	
PPE-403 & PPE-403L	4(3,1)	PPE-404L	3(0,3)	
PPE-405	3(0,3)	PPE-406	3(0,3)	
PPE-407	3(3,0)	PPE-408	3(3,0)	Optional
PPE-312	3(3,0)	MGT-413	3(3,0)	
	16(24)		**15(27)**	

EXAMPLE (ELABORATED)

Rules: 1st and 2nd Year (18 CR not exceeding 26 CtH), 3rd and 4th year (20 CR not exceeding 30 CtH)

Semester 1 (Fall)

PPE-101	Engineering & Polymeric Materials	3(3,0)	No Pre-requisite
PPE-103 & PPE-103L	Industrial Stoichiometry	4(3,1)	No Pre-requisite
CS 101	Computing Fundamentals	3(2,1)	

A 100 level course from Physics or Chemistry Department

Department Recommendation:

CY 161	*Polymer Chemistry-I*	*3(2,1)*	

A 100 level course from Mathematics Department

Department Recommendation:

MA 113	*Calculus and Analytical Geometry*	*3(3,0)*	

Semester 2 (Spring)

PPE-102 & PPE-102L	Fundamentals of Polymer Engineering	4(3,1)	No Pre-requisite
PPE-104 & PPE-104L	Particle Technology	3(2,1)	No Pre-requisite
PPE-106 & PPE-106L	Fluid Flow	4(3,1)	No Pre-requisite
MA-118	Applied Mathematics & Statistics	3(3,0)	
HU 111L	Communicational Skills	1(0,1)	
IS 101	Islamic and Pakistan Studies I or	3(3,0)	
	HU 101 Ethics and Pakistan Studies-I		

Semester 3 (Fall)

PPE-201 & PPE-201L	Polymer Structures & Synthesis	4(3,1)	CY-161
PPE-202	Polymer & Process Industries	3(3,0)	No Pre-requisite
PPE-203	Chemical Engineering Thermodynamics	3(3,0)	No Pre-requisite
PPE-204 & PPE-204L	Heat Transfer	4(3,1)	PPE-106
IS 201	Islamic and Pakistan Studies II or	3(3,0)	
	HU 101 Ethics and Pakistan Studies-II		
ME 100L	Workshop Practice	1(0,1)	
	(Smithy, Machine, Fitter, Carpentry Shop, Electrical Shops & Model Making)		

Semester 4 (Spring)

PPE-105	Petroleum Refining & Petrochemical Engineering	3(3,0)	No Pre-requisite
PPE-205 & PPE-205L	Mass Transfer	4(3,1)	PPE-106
PPE-206	Environmental Engineering & Process Safety	3(3,0)	PPE-202
PPE-302 & PPE-302L	Polymer Reaction Engineering	4(3,1)	PPE-201
HU 221	Technical Writing & Presentation Skills	3(3,0)	

Semester 5 (Fall)

PPE-301	Mechanical Properties of Polymers	3(3,0)	PPE-101
PPE-305	Polymer Thermodynamics	3(3,0)	PPE-203
PPE-307	Transport Phenomena	3(3,0)	PPE-205
PPE-309 & PPE-309L	Process Engineering Computing	3(2,1)	PPE-204, PPE-205
PPE-311	Engineering Economics	3(3,0)	
MA-346	Numerical Methods	3(3,0)	MA 110

Semester 6 (Spring)

PPE-303	Polymer Compounding	3(3,0)	PPE-102
PPE-304 & PPE-304L	Simulation in Polymer Processing	3(2,1)	PPE-102
PPE-306 & PPE-306L	Polymer Analysis & Characterization	4(3,1)	PPE-102
PPE-308 & PPE-308L	Polymer Processing Design	4(3,1)	PPE-102 & PPE-307
PPE-310 & PPE-310L	Instrumentation & Control	4(3,1)	PPE-205

Semester 7 (Fall)

PPE-401	Polymer Rheology	3(3,0)	PPE-307
PPE-403 & PPE-403L	Process Plant Design	4(3,1)	PPE-204,-205,-302,-311
PPE-405	Final Year Project-I	3(0,3)	PPE-201
PPE-407	Polymer Composites	3(3,0)	PPE-301
PPE-312	Engineering Management	3(3,0)	

Semester 8 (Spring)

PPE-402	Polymer Product Design	3(3,0)	PPE-102, PPE-301
PPE-404L	Plant Design Practice	3(0,3)	PPE-403 & PPE-403-L
PPE-406	Final Year Project-II	3(0,3)	PPE-405
PPE-408	Smart Polymers	3(3,0)	PPE-201

A 300 or 400 level course of Management

Department Recommendation:

MGT 413	*Entrepreneurship*	*3(3,0)*