FACULTY OF ENGINEERING

Syllabus for the

T.E (Polymer Engineering)

(w.e.f 2010-2011)

UNIVERSITY OF PUNE

Structure of Polymer Engineering
T. E. Polymer Engineering
[2008 Course]

TERM – I

Subject Code No.	Subject	Teaching Scheme			Examination Scheme				Total
		Theory	Practical	Drawing	Paper	TW	Practical	Oral	
309361	Polymer Chemistry - I	4	4	-	100	50	-	-	**150**
309362	Polymer Materials	4	2	-	100	25	50	-	**175**
309363	Polymer Structure Property Relationship	4	2	-	100	50	-	25	**175**
309364	Design Equipment & Machinery Element	4	2	-	100	50	-	-	**150**
309365	Mass Transfer and Reaction Engineering	4	-	-	100	-		-	**100**
	TOTAL	**20**	**10**	**0**	**500**	**175**	**50**	**25**	**750**

TERM – II

Subject Code No.	Subject	Teaching Scheme			Examination Scheme				Total
		Theory	Practical	Drawing	Paper	TW	Practical	Oral	
309366	Mathematical Methods for Polymer Engineers	4	-	-	100	-	-	-	**100**
309367	Polymer Chemistry – II	4	2	-	100	-	50	-	**150**
309368	Instrumentation and Process Control	4	2	-	100	25	-		**125**
309369	Polymer Processing Operations – I	4	2	-	100	50	-	25	**175**
309370	Polymer Rheology	4	2	-	100	25	-	25	**150**
309371	Seminar	-	-	2	-	50	-	-	**50**
	TOTAL	**20**	**8**	**2**	**500**	**150**	**50**	**50**	**750**

309361 Polymer Chemistry - I

Teaching Scheme				Examination Scheme		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
Practicals	:	4 hrs./Week		T.W.	:	50 Marks
				Total	**:**	**150 Marks**

Objective

To provide the basic building blocks of polymer science and engineering by coverage of fundamental polymer chemistry.

Section – I

Unit I	**Fundamentals of Polymer Science**	**8 hrs.**

Introduction, Definitions, Classification of polymers, Concept of functionality, Polydispersity and Molecular weight [MW], Various average molecular weight of polymers, Various methods of determination of MW, Molecular Weight Distribution [MWD], Various methods of determination of MWD.

Unit II	**Chain Polymerization**	**8 hrs.**

Free radical polymerization: Initiators, polymerization mechanism, Chain transfer, Inhibitors and retarders, Ionic polymerization: Initiators, Mechanism, Kinetics of free radical, cationic and anionic polymerization reactions, An overview of following polymerization techniques - Bulk, solution, suspension, emulsion, solid phase and gas phase polymerization.

Unit III	**Step Polymerization**	**8 hrs.**

Mechanism of Polycondensation, Polyaddition and Ring-opening polymerization, Need for stoichiometric control, Gelation, Crosslinking, Carother's equation, Kinetics of step polymerization, An overview of following polymerization techniques- Interfacial and melt polymerization.

Section - II

Unit I V	**Step and Chain Copolymerization**	**8 hrs.**

Step Copolymerization: Introduction, Types, Methods of synthesis, Chain Copolymerization: Introduction, Types, Copolymerization equation, Monomer reactivity ratio, Applicability of copolymerization equation, Types of Copolymerization behavior, Sequence length distribution, Q-e scheme, Commercial applications of Copolymerization.

Unit V	**Polymer Modifications, Degradation and Plastic Waste Management**	**8 hrs.**

An overview of various polymer modification reactions viz. Hydrolysis, Acidolysis, Aminolysis, Hydrogenation, Addition and substitution, specific group reactions like hydroxyl, aldehyde, ketone, carboxyl, amino groups.
Introduction to polymer degradation, Study of polymer degradation based on various factors or agents, Management of plastic waste in the environment – Recycling, Incineration and Biodegradation.

Unit VI	Stereochemistry of Polymerization	8 hrs.

Introduction, Types of isomerism in polymers, Properties of stereo-regular polymers, Forces of stereo regulation in alkene polymerization, Ziegler – Natta polymerization, Metallocene catalyst.

Practical [any 08]

1. Study of various laboratory practices like material handling, handling laboratory equipments, basic laboratory techniques etc.
2. Comparative study of Bulk and Solution polymerization techniques.
3. To synthesize polymer by Suspension polymerization technique.
4. To synthesize polymer by Emulsion polymerization technique.
5. To synthesize polymer by Interfacial polymerization technique.
6. To determine molecular weight by Viscometry technique.
7. To study kinetics of catalyzed polyestrification.
8. To study kinetics of uncatalyzed polyestrification.
9. Casting of PMMA sheets.
10. Finding out of Reactivity ratios for Styrene-MMA copolymer
11. Synthesis of Cellulose acetate from Cellulose
12. Synthesis of styrene-maleic anhydride copolymer
13. Synthesis of epoxy resin.
14. To synthesize UF / MF / PF resin

Reference books :

1. Polymer Chemistry - An Introduction, **M.P. Stevens,** Oxford University Press, 1999.
2. Principles of Polymerization, **George Odian,** Wiley Inerscience John Wiley and Sons, [4th edition]
3. Polymer Science, **V.R. Gowarikar,** New Age International [P] Ltd. Publisher, 1986 [1st edition]
4. Text book of Polymer Science, **F.W. Billmeyer Jr.,** Inter science Publisher John Wiley and Sons, 1962, [3rd edition].
5. Polymer Molecular Weight, **Slade, Jr.** Vol. I and II.: M. Dekker, New York, 1975.
6. Polymer Science and Technology, **Joel R. Fried**, PHI publications pvt. Ltd., New Delhi [2nd edition]

309362 Polymer Materials

Teaching Scheme				**Examination Scheme**		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
Practicals	:	2 hrs./Week		T.W.	:	25 Marks
				Practical	:	50 Marks
				Total	:	**175 Marks**

Objective

To impart the knowledge pertaining to different polymeric materials with structure-property relationship view as a basis so as to enable polymer engineers to select appropriate materials for new and demanding applications.

Section –I

Unit I		**8 hrs.**

Concepts related to Thermoplastics & Thermosets, Commodity, Engineering & High performance polymers.

Industrial manufacturing processes, properties, applications, brief idea about compounding & processing for;

- Polyethylenes [LDPE, HDPE, LLDPE, UHMHDPE, EVA, etc.]
- Polypropylene and its copolymers
- Polyvinyl acetate and polyvinyl alcohol

Unit II		**8 hrs.**

Industrial manufacturing processes, properties, applications, brief idea about compounding & processing for;

- Polyvinyl chloride and polyvinylidene dichloride
- Fluoropolymers [PTFE, PVDF]
- Styrenics [GPPS, HIPS, ABS, SAN, expandable PS]

Unit III		**8 hrs.**

Industrial manufacturing processes, properties, applications, brief idea about compounding & processing for;

- Acrylics
- Polycarbonate
- Cellulosics

Section – II

Unit IV		**8 hrs.**

Adhesives paints & coatings

Basic principles, functional uses, types of adhesives. Solvents, fillers, plasticizers, hardeners, primers, thickening agents used with adhesives.

Terminology like paints varnish stains, lacquer, primer.
Basic principles, formulations, binders, solvents, pigments, additives.

Unit V		8 hrs.

Fundamentals of rubbers – Basic terminologies such as raw rubber, vulcanisate, etc.
Molecular requirements for a material to function as an elastomer.
Outline of raw rubber technology – concepts of mastication, compounding, vulcanization in brief.
Introduction to latex technology.

Unit VI		8 hrs.

Industrial manufacturing processes, properties, applications, brief idea about compounding & processing for;

- Natural rubber [NR]
- Styrene-Butadiene rubber [SBR]
- Butyl rubber
- Thermoplastic elastomers
- Polychloroprene rubber
- Nitrile rubber

Practicals [any 08]

Identification of
1] Polyolefin [LD, HD, PP]
2] Polyamides [Nylon 6, 66]
3] Polyacetals
4] Cellulose acetate
5] Phenol formaldehyde
6] PET, PBT
7] Acrylics
8] PC
9] PS
10] PVC
11] Different types of elastomers
12] Polyester resin
13] Epoxy resin

Reference Books :

1. Plastic Materials, **J.A. Brydson**, Heinemenn / Elsevier Publisher,7th edition,2005
2. Manufacture of Plastics, **S.W. Mayo**, Reinhold Publishing Corporation, Chapman & Hall, Ltd. London, 1964.
3. Fundamentals Principles of Polymeric Materials, **S.L. Rosen**, John Wiley Publisher,2nd edition,1993.
4. Plastics Engineering Handbook, **J. Fredos,** Van Nostrand Reinhold , Newyork, 2nd-3rd edition 1976.
5. Plastics Materials Handbook **A.S.Athalye**, Multi Tech Publisher Mumbai,3rd edition,1995
6. Handbook of Plastics Materials and Technology, **I. Rubin**, Wiley Inter. Sc. Publisher.

309363 Polymer Structure & Property Relationship

Teaching Scheme				Examination Scheme		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
Practicals	:	2 hrs./Week		T.W.	:	50 Marks
				Oral	:	25 Marks
				Total	**:**	**175 Marks**

Objective

The course tries to rationalize vast body of information available about structure, properties and application of different polymers. The end properties are studied as a function of type of atoms, polymer structure, molecular weight and molecular weight distribution, molecular orientation, crystallinity, types of secondary forces among the chain and molecular flexibility.

Section I

Unit I	Submolecular structure	8 hrs.

- Chemical composition of polymer molecules & its effect on properties like mechanical, chemical, thermal, electrical, optical etc.
- Monomeric ingredients required in final polymer composition & their effect on properties & applications.
- Types of additives and its role on end properties.
- Types of bonds in polymer structure & their effect on properties mechanical, chemical, thermal, electrical, optical etc.

Unit II	Molecular structure	8 hrs.

- Molecular size & shape & its effect on processability & various other properties such as mechanical, chemical, thermal, electrical, optical etc.
- M.W. & M.W.D & its effect on various properties like mentioned above.
- Conversion methods from low to high m.w. during various processing techniques.

Unit III	Molecular Flexibility	8 hrs.

- Molecular Flexibility & freedom of rotation of bonds & thus effect on properties like Tg, Tm, crystallinity, etc.
- Structural restriction to rotation & thus effect of properties mechanical, electrical, optical etc..
- Effect of copolymer & blends on polymer properties.
- Intermolecular order 1^{st} and 2^{nd} order transition, super cooled state, fringed micelle theory, spherulitic growth & its effect on various properties.
- Effect of chemical groups on adhesion, theories of adhesion.

Unit IV	Intermolecular structure	8 hrs.

- Intermolecular order, amorphous & crystalline state. Factors leading to crystallinity & its effect on various properties like processing, mechanical, thermal etc.
- Thermodynamic and kinetic factors affecting rate of crystallization.
- Orientation & relation between crystallization & orientation. Effect of orientation on various polymer properties like mechanical, chemical, thermal, electrical, optical etc.
- Relation between Tm and Tg and their significance.

Unit V	Intermolecular Bonding	8 hrs.

- Intermolecular bonding forces like London Dispersion Forces [LDF], induced & permanent dipole. Effect of these forces on structure & properties like solubility, melting, CED, permeability etc.
- Ionic bonding, cross linking, polarity and their effect on polymer properties like mechanical, chemical, thermal, electrical, optical etc..

Unit VI	Supermolecular structure	8 hrs.

- Multiple phases & macrostructure.
- Temporary heterogenity for processing.
- Chemical microheterogenity.
- Complex multi component: total macro structures.

List of experiments: [any 08]

1] To study DSC, its working and applications along with interpretation of few spectras for various polymer systems.
2] To study TGA, its working and applications along with interpretation of few case studies from thermo gram of polymer.
3] To study FTIR spectroscopy working & application and to understand the identification chart to identify polymer from the spectra obtained. Also to study various other parameters of polymer system, like blends, co-polymers, additives, etc.
4] To study working of GPC to find M.W., M.W.D. Polydisperity, etc.
5] To study X-ray diffraction, its working and application along with interpretation of the d-spacing from the spectra obtained & thus have morphology understood.
6] To find out the swelling of rubber in various solvents and thus find out its degree of crosslinking, etc.
7] To find out the permeability of LDPE film towards various solvents; & study the importance of barrier properties & factors affecting them.
8] To study & find out the % of vinyl acetate in EVA.
9] To study preparation, working importance, and application of thin layer chromatography [TLC].
10] To study the relationship between MFI & VA content in EVA.
11] To study the importance of scanning electron microscope for studying the morphology of polymer system.
12] To develop & study the growth of spherulites.

Reference Books :

1. Polymer Structure, Properties and Applications, **Rudolph.D. Deanin,** Plastics World, Cahners Publication, 1972.
2. Introduction to Polymer Crystallization, **Allan Sharples,** St. Martin's Press, N.Y., 1966.
3. Macromolecular Physics, **Berhard Wunderlich**, Academic Press, N.Y.
4. Properties and Structure of Polymers, **A.V. Tobolsky, John Wiley & Sons,** N. Y., 1960.
5. Structure and Properties of Polymers, **H.V. Boenig,** J.Wiley & Sons, N.Y., 1973.
6. Text book of Polymer Science, **Fred W. Billmeyer Jr.,** Inter science Publisher John Wiley and Sons, [3rd edition] ,1962.
7. Polymer Chemistry & Physics of Modern Materials, **J.M.G. Cowie,** Chapman & Hall [2nd edition].
8. Introduction to physical polymer science, **L.H. Sperling ,**Wiley Interscience [3rd edition]. 2001
9. Physical Chemistry of Polymers, **A. Tager**, MIR Publishers [Moscow],1978

309364 Design of Equipment and Machine Elements

Teaching Scheme				Examination Scheme		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
Practicals	:	2 hrs./Week		TW	:	50 Marks
				Total	**:**	**150 Marks**

Objective

To impart practical and theoretical knowledge of machine and process equipment design so as to enable students to understand machines used in the polymer industry.

Section - I

Unit I		**6 hrs.**

Fundamentals of Design: Methodology, steps in design, Mohr Circle, selection of materials and material standards,BIS standard, theories of failures for biaxial stress system, factor of safety, stress concentration.

Types of keys, design of key.
Couplings and their types, design of muff coupling, compression coupling, flange coupling, flexible coupling.

Unit II		**8 hrs.**

Design of shafts subjected to twisting moment, bending moment, combined twisting & bending moment, fluctuating loads, Torsional Rigidity.

Flat belt, material, types of flat belt drive, slip of belt, creep of belt, length of open belt drive, length of cross belt drive, power transmitted by a belt, ratio of driving tensions for flat belt drive, centrifugal tension maximum tension in a belt, initial tension in belt.

Unit III		**8 hrs.**

Classification of bearings, design of bush and journal bearings. Types and design of thrust bearing. Types of gears, cone and pulley arrangement, sliding gear arrangement, sliding key mechanism, Norton gear box, clutched systems, common ratio & number of spindle speed steps.

Section - II

Unit IV		**8 hrs.**

Pumps and Valves: Positive displacement pumps used in processing machines, like vane, gear, axial etc. Directional control valves, flow control valves, Pressure control valves, relief valves etc.

Unit V		**8 hrs.**

Introduction to digital and proportional hydraulics,
Hydraulic Drives : Drives for clamping mechanism in injection molding machine – toggle type, conventional hydraulic, hydro mechanical and electric.

Unit VI		**12 hrs.**

Design of Pressure Vessels : Design of shell, head, flanges, nozzles.
Design of Reaction vessel [Kettles] : Jackets and coils for heating and cooling.

List of Drawings :

Three assignments based on the following topics.

[I] Reaction vessel design.

(II) Study of basic hydraulic circuits.

1. Unloading circuit.
2. Regenerative circuit.
3. Sequencing circuit.
4. Counter balance circuit.
5. Breaking circuit.
6. Feed circuit
   a. Meter in flow control
   b. Meter out flow control
   c. Bleed off flow control
7. Rapid advance to feed circuits
   a. Using meter out circuit.
   b. Using meter in circuit.
8. Open circuit for reversible hydrostatic drive.
9. Reversible closed circuit.

[III] Basic conventional hydraulic circuits in injection molding machine –
1. Clamping 2. Plasticizing 3. Injection

Reference Books :

1. Process Equipment Design, **M.V.Joshi,** Macmillan India Publication ,3rd edition,1996.
2. Injection Molding, Theory and Practice, **Irvin Rubin,** John Wiley & Sons Publication, Newyork,1972.
3. Elements of Machine Design, **Pandya and Shah,** Charotar Book Stall,2006.
4. Fundamentals of Machine Component Design,**Robert C. Junawel, Kurt M.Marshek,** John Wiley & Sons , ,August 2005.
5. Machine Tool Engineering, **G.R. Nagpal,** Khanna Publication , 2004.
6. A text book of Machine Design,**R.S.Khurmi and K.K.Gupta,**S.Chand Publication,2009
7. Indusrial Hydraulics Manual, **Vickers ,** .[3rdedition] **,**2004.

309365 Mass Transfer & Reaction Engineering

Teaching Scheme				Examination Scheme		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
				Total	**:**	**100 Marks**

Objective

1. To provide theoretical understanding of various inter-phase mass transfer operations such as diffusion, vapor-liquid, liquid-liquid and gas-liquid systems, humidification and drying.
2. To understand basic principles of chemical reactor design for homogeneous reactions.

Section - I

Unit I	**Diffusion**	**8 hrs.**

Introduction to mass transfer : Various industrial important mass transfer operations , their classification. Choices of separation methods, methods of conducting mass transfer operation design principle. Molecular diffusion in fluids, steady state diffusion under stagnant & laminar flow conditions, diffusivity of gases & liquid, diffusion in solids & its application. Mass transfer coefficient, eddy diffusion Two film theory, surface renewal theory and penetration theory. Mass, heat & momentum analogies.

Unit II	**Absorption and Distillation**	**8 hrs.**

Raoults Law & Henry's law. Equipment for gas liquid operations, absorption equilibrium, ideal non-ideal solution, modified raoults law. Selection of solvent for absorption, design concept of absorption.
Distillation - Introduction, relative volatility, Types of distillations, concepts designs and operation for distillation.

Unit III	**Humidification and Drying**	**8 hrs.**

Basic concepts of humidification & psychrometric chart construction, humidification and dehumidification operations, design calculation, cooling tower principle & operation, types of equipment, design calculation. Theory & mechanism of drying, drying characteristics of material, batch and continuous drying, calculation for continuous drying, drying equipment, design and performances of various drying equipments.

Section - II

Unit IV	**Fundamental of Reaction Kinetics**	**8 hrs.**

Chemical Reactions: Rate of chemical reactions, variable affecting the reaction rate, order of reaction, reaction rate constant, elementary and non-elementary reaction mechanism. Arrhenius equation, Collision theory, predictability of reaction rate. Kinetics of homogeneous chemical reactions, rate equations for simple and complex reactions,

Unit V	**Ideal Reactor**	**8 hrs.**

Interpretation of reactor data in constant volume and variable volume batch reactions, integral and differential method of interpretation of batch reactor.
Classification of chemical reactor, interpretation of reactor data in flow reactions. Reactor design for homogeneous, isothermal operations, & batch, semi batch, plug flow and continuous stirred tank reactor. Concepts of space time, space velocity and residence time in flow reactors,

Unit VI	**Chemical Reactor Systems**	**8 hrs.**

Comparison of single reactors like batch, plug flow and CSTR for first and second order reactions. Multiple reactors system, plug flow reactions in series and for parallel equal sized Constant Stirred Tank Reactor's [CSTR's] in series. Introduction to polymer reactors.

Reference Books:

1. Unit operations in Chemical Engineering, **McCabe, Smith & Peter Harriot** McGraw Hill, 7th edition 1993.
2. Mass Transfer Operations, **Treybal** McGraw Hill,3rdedition, 1980.
3. Chemical Engineering vol. 1 to 2, **Richardson Coulson,** Pergamon Press,4th edition,1990
4. Chemical Reaction Engineering, **O. Levenspiel, John Wiley 3rd edition,2007**
5. Chemical Reaction Engineering, **Ians Netcalfe,** Oxford University Press, 1997.
6. Chemical Reaction & Chemical Reactor, **George W. Roberts,** John Wiley & Son, Inc. 2008.
7. Element of Chemical Reaction Engineering, **Scott Fogler,** Prentice Hall,3rdedition,1999
8. Mass Transfer Fundamental, **Anthony L. Hines,** Prentice Hall, 1985.
9. Mass Transfer Operation, **Treybal R.E.,** McGraw Hill, ,3rd edition. 1980
10. Chemical Engineering vol. I & II, **Richardson Coulson**, Pergamon Press, 1977.
11. Chemical Reaction Engineering, **O. Levenspiel,** John Willey, 2007, [3rd edition].

309366 Mathematical Methods for Polymer Engineers

Teaching Scheme				Examination Scheme		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
				Total	**:**	**100 Marks**

Section - I

Unit I		**8 hrs.**

Calculus of Finite difference , Finite difference Operators , Newton's , Lagrange's & Stirling's Interpolation formulae .
Numerical differentiation & Numerical Integration. Error analysis.

Unit II		**8 hrs.**

Solution of Algebraic & Transcendental equations, Bisection Method, Method of False position , Newton-Raphson method ,Method of Successive Approximation, Convergence & Stability Criteria.
Solution of System of Simultaneous Linear Equations, Gauss Elimination Method, Gauss-Seidel Method, Jacobi's Method.
Method of Least Square for curve fitting.

Section - II

Unit III		**9 hrs.**

Ordinary differential equations, initial value problems, Euler's method, Modified Euler's Method, Runga – Kutta method, Overview of the step – size control and error estimation. Stability of algorithms, Stiff ordinary Differential Equations and Gear's technique. Boundary value problems, Solutions of Ordinary and Partial differential equations using finite difference techniques.
Overview of finite element methods.
Computer algorithms for the various numerical methods described above.

Unit IV		**9 hrs.**

Linear Programming, Formulation & Solution, Simplex method, Duality.

Unit V	**Statistics and Probability**	**8 hrs.**

Correlation and Regression, Probability, Probability Distributions, Binomial, Normal and Poisson Distribution, Chi-square Distribution, Beta Distribution, Weibull Distribution,

Random Sampling, Estimation of Parameters, Testing of Hypothesis, Student t test, F-Test

Unit Vi	**Tensors**	**8 hrs.**

General curvilinear co-ordinate systems; contravarient, covariant and mixed tensors, metric tensor, Christoffel symbols, covariant derivative, Divergence, Laplacian & curl, Applications of tensors.

Reference Books :

1. Gupta S.K.'Numerical methods for Engineers',New Age International Publishers [previously Wiley Eastern Ltd.],2nd edition 1995.
2. Jain M.K., Iyengar, S.R.K., Jain,R.K., 'Numerical methods for scientific and Engineering computation' , Wiley Eastern Ltd,2nd edition,1985.
3. Kreyszig F.'Advanced Engineering Mathematics',John Wiley Eastern Ltd,8th edition,1999.
4. Ariken E.'Advanced engineering methods in the physical science,' Academic press.
5. Boas M.L.'Mahtematical methods in the physical science,' J. Wiley and sons,2nd edition,1966
6. Aris R.'Vectors, tensors and the basic equations of fluid mechanics,' Dover Publication Inc.,1962
7. Probability and statistics in Engineering William W.Hines, D.C.Montgomery, John Wiley & Sons, Inc 4th edition
8. H.A. Taha : ` Operations Research – An Introduction', Prentice-Hall of India Pvt. Ltd, 4th edition,2003.
9. Hira-Gupta, 'Operations Research', S. Chand & Company, 3rd edition,1993.

309367 Polymer Chemistry – II

Teaching Scheme				Examination Scheme		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
Practicals	:	2 hrs./Week				
				Practical	:	50 Marks
				Total	:	**150 Marks**

Objective

To impart knowledge of synthesis, formulation an application of various specific polymers of present day relevance to the industry. A sound understanding of these polymeric materials would equip the students for careers in manufacturing industries. Topics in recent advances in polymer science would keep students updated about the frontier areas of research and development.

Section – I

Unit I	**Thermosetting Resins**	**8 hrs.**

Synthesis, formulation, curing, properties and applications in brief of following resins:

1. Phenolic Resins
2. Amino Resins
3. Silicone Resins

Unit II		**8 hrs.**

Synthesis, formulation, curing, properties and applications in brief of following resins:

1. Saturated polyester resins
2. Unsaturated Polyster Resins and alkyds
3. Vinyl ester resins

Unit III		**8 hrs.**

Synthesis, formulation, curing, properties and applications in brief of following resins:

1. Epoxy Resins
2. Polyurethane Resins

Section – II

Unit IV		**8 hrs.**

Synthesis, formulation, curing, properties and applications in brief of following resins:

1. Polyacetals
2. Polyamides
3. Polyimides

Unit V	**High Performance Polymers**	**8 hrs.**

Synthesis, properties and applications of following materials:

- Poly [phenylene oxide]
- Poly [phenylene sulphide]
- Polysulphone
- Poly[ether ketone]/ Poly[ether-ether ketone]

Unit VI	Recent Trends in Polymer Science	8 hrs.

Membrane science and technology, Biomedical engineering and drug delivery, Conducting polymers, Nano-composites; Liquid crystalline polymers, Brief introduction to plasma polymerization,

Practicals [any eight]

1. Study of PVC - determination of % chlorine, K-value, plasticizer absorption test by Burette method.
2. Study of Epoxy - determination of epoxy value and epoxy equivalent.
3. Study of Unsaturated polyester resin - Acid value determination and curing characteristics
4. Determination of molecular weight of PEG resin by end group analysis technique.
5. To find out Strength of Formalin solution
6. To find out Saponification value of oil samples
7. To determine functionality of given monomer / chemical compound.
8. To synthesize Polvinyl alcohol from Polyvinyl acetate.
9. Preparation of cellophane film.
10. To determine purity of given plasticizer.
11. to determine purity of adipic acid.
12. Melting point and density determination of polymers.
13. Filler content determination.

References Books :

1. Plastics Materials, **J. Brydson** ,Heinemen / Elsevier, [7th edition], 2005
2. Handbook of Thermoset Plastics, **S.H. Goodman** [ED] Noyes Publisher, [2nd edition], 1986.
3. Organic Polymer Chemistry, **K.J.Saunders,** Chapman & Hall, 1988.
4. Encyclopedia of Chemical Technology, Volume 17, **Kirk & Othmer**, John Wiley & Sons, [4th edition], 1996.

5 Polymer Science and Technology, **Joel R. Fried**, PHI publications pvt. Ltd., New Delhi [2nd edition]

309368 Instrumentation and Process Control

Teaching Scheme				Examination Scheme		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
Practicals	:	2 hrs./Week		T.W.	:	25 Marks
				Total	**:**	**125 Marks**

Objective

Sensor Network and computerized control system have become indispensable part of process industry. This course intends to impart basis understanding of instrumentation systems used in polymer industry and different control strategies needed to optimize process plants.

Section – I

Unit I	**Introduction to Measurement System**	**7 hrs.**

Measurement system elements, classification of Instruments, Static and Dynamic Characteristics of instruments, Calibration, Sources of error with measuring instruments, Designing of measuring system, Basics of sensing elements, Signal conditioning, Data display with some examples.

Unit II	**Temperature and Pressure Measurements**	**8 hrs.**

Temperature Measurement Instruments such as Expansion Thermometers, Filled System Thermometers, Thermo electricity Based: Industrial thermocouple, response of thermocouples and other Electrical Temperature based sensors, Radiation and optical pyrometers.
Pressure Measurement Instruments such as Liquid Column Elements, Elastic Element Gauges, Electrical Transducer, Forced Balanced Devices.

Unit III	**Level, Flow, Viscosity and Density Measurements**	**7 hrs.**

Direct and Indirect measurement of Liquid Level, Different Head flow meters, area flow meters, Total Flow measuring instruments, Viscosity Measurements of polymer solutions and polymer melt, and density measurements systems.

[Section – II]

Unit IV	**Introduction to Process Control**	**7 hrs.**

Introduction to Process control, Designing aspects of Process control system, control system performance, mathematical modeling principles used for process control, Dynamic response of linear open loop systems such as First order system, second order system, first order system in series with physical examples.

Unit V	**Feedback Control Loop**	**8 hrs.**

Introduction to control loop, open loop and closed loop, basic elements of closed loop control system, feedback control system, closed loop transfer function, open loop transfer function, multiple closed loop transfer function, effect of disturbances, modes of control action and control valve, Transient response of simple control system, controller tuning.

Unit VI	**Advanced Process Control**	**7 hrs.**

Introduction to Advanced process control system, Feed forward, cascade, ratio control with different application, Introduction to Digital control, introduction to discrete-time system, Introduction to Programmable Logic Control, Supervisory control and data acquisition systems. Distributed control systems, Different examples of Microprocessor based control system used for chemical and polymer manufacturing such as control of continuous and batch polymerization processes.

List of Practicals: [Any 08]

1. Characteristics and calibration of temperature measuring instrument.
2. Characteristics and calibration of pressure measuring instrument.
3. Characteristics and calibration of level measuring instrument.
4. Characteristics and calibration of flow measuring instrument.
5. Control valve characteristics
6. Estimation of response of first order system.
7. Estimation of damping coefficient for U tube manometer.
8. Experiments on Proportional integral and derivative control actions.
9. Controller tuning using Ziegler Nichols rules.
10. Feedback temperature, pressure, level and flow control loop.
11. Computer based control of polymer processing equipment such as injection molding machine.
12. Study of Programmable logic control.
13. Experiment on cascade control.
14. Study of control stability analysis.
15. Study of Data Logger.
16. Experiment on screw speed measurements.

Reference Books :

1. Industrial instrumentation, **Eckman D.P.** Wiley Eastern, [16th edition],1991.
2. Process systems analysis and control, **Coughanowr Donald R.,** McGraw Hill, [2nd edition], 1991
3. Chemical process control : An introduction to theory and practice, **Stephnopoulos George,** Prentice – Hall India, 2002.
4. Process control: Designing processes and control systems for dynamic performance, **Marlin T.,** McGraw – Hill, [2nd edition] 2004.
5. Principles of industrial instrumentation, **Patranabis D.**, Tata McGraw Hill, New Delhi, [2nd edition], 2004.
6. Instrumentation measurement and analysis, **Nakra, B.C., Choudhary K.K.,** Tata McGraw Hill, New Delhi, [2nd edition], 2004.
7. Process control instrumentation technology,**Johnson C.D.,**Pearson Prentice–Hall International, [4th edition], 1996.
8. Process / industrial instruments and control handbook, **Considine D.M.,** McGraw – Hill, [1st edition] ,2006
9. Process analyzer technology, **Clevett J.G.,** Wiley, New York 1986.
10. Process instrumentation and control, **A.P. Kulkarni,** Nirali Publication, [1st edition], 2008.
11. Industrial Control and instrumentation, **Bolton W.,** University Press, [1st edition],1991.
12. Handbook of Plastics Test Method, Handbook of Plastic Testing Technology, **R.P. Brown,** A. Wiley - Inter science Publication, 1981.

309369 Polymer Processing Operations - I

Teaching Scheme				Examination Scheme		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
Practicals	:	2 hrs./Week		T.W.	:	50 Marks
				Oral	:	25 Marks
				Total	**:**	**175 Marks**

Objective :
The subject prepares the student for understanding of various polymer processing operations from rheological and processing equipment point of view. The subject deals with basic processes like extrusion, compression moulding, transfer moulding and various specialized injection moulding processes.

Section I

Unit I	**Extrusion Process and Control**	**7 hrs.**

Fundamentals of the extrusion process, basic operation, Analysis of flow through Extruder, Drag flow, Pressure flow, solids conveying, hopper, feeding mechanism, drag induced conveying, melting mechanism, power consumption in metering zone, output and power requirements in a single screw extruder, extruder design, extruder drives : types and selection, screw design - construction and operation, Barrier screws, Vented screws. Grooved screw barrel systems.

Unit II	**Extrusion Plants and Downstream Equipment**	**7 hrs.**

Downstream equipment and Auxiliary units for extrusion lines. Extrusion process and plants for profiles, pipes, blown film [monolayer and multiplayer], monofilaments, strapping, cast film, sheet, cable, coating and laminating. Extrusion dies for specific products lines, controlling the extrusion process, heat-transfer and heat-content consideration. Equipment for sizing, cooling, take off, cutting, winding, orientation, processing parameters and their effect on product quality, Measurement and control, Trouble shooting.

Unit III	**Injection Moulding**	**7 hrs.**

Moulding process, cycle, stages involved PVT diagram and injection moulding cycle. Fill and pressure phase analysis, different velocity – pressure switch – over techniques. Orientation in injection moulding and its effects. Characteristics of typical materials and injection molding of these materials, processing parameters and their effect on product quality, process control in injection molding, close loop and open loop machines, trouble shooting in injection molding, machines specifications and selection.

Section – II

Unit IV	**Specialized Molding Processes – I**	**7 hrs.**

Gas assist injection moulding, Two colour pattern making injection moulding, Two colour two component injection moulding machine and process, injection moulding of thermosets, low pressure injection molding, injection – compression molding, injection moulding of DMC, reaction injection moulding, injection moulding of elastomers.

Other polymer processing operations - Such as dip coating, slush moulding, polymer casting ,matched metal moulding, Liquid reservoir moulding, Solid phase forming.

Unit V	**Specialized Processes – II**	**7 hrs.**

Co-extrusion of sheet and film, co-extrusion of profiles, tubing and other products; Extrusion of cellular / foamed plastic products, equipment requirement for foamed product, down stream equipments for foamed product. Process control of extrusion process, control of down stream equipments. Specialized produces and processes like netting, magnetized plastics strip, extrusion of hollow core panel, sandwich panel, coiled extrusion, twisted rod extrusion.

Unit VI	Compression moulding	7 hrs.

Basic principle and moulding cycle, Moulding materials, effect of bulk factor, Flow properties, Cure time, temperature and pressure on moulding cycle; effect of preheating and performing. Defects & remedy in presses for moulding; specifications; controls calculations of number of cavities based on rate of production. Basic principles of mould design; cavity, punch; methods of ejection, heating of moulds. Types of compression moulds. Moulding of thermoplastics, thermosets, Dough moulding compounding, SMC. Analysis of compression moulding; flow rate, compaction force for moulding.

Transfer moulding - Basic principle and moulding cycle. Advantages & limitation of the process. Types - integral pot and auxiliary ram transfer. Process parameters and their effect on product quality. Moulding defects, causes & remedies; Transfer moulding of thermosets, Transfer moulding of DMC. Types of transfer presses, specifications. Clamping tonnage calculations, moulding defects and applications, design of transfer moulds. Transfer moulding, materials, flow properties. Auxiliary plant equipments like, performing machines, safety devices.

List of experiments: [any 08]

1. Study and working of compression and transfer molding of PF.
2. Study of transfer moulding technique.
3. Study and working of blown film plant.
4. To study the effect on film properties by varying haul – off speed, temperature, blow ratio, screw speed, cooling etc.
5. Study of Gas-Assisted injection molding.
6. To plot screw and die characteristics and to study the effect of variation of process parameters on screw & die characteristics.
7. Study of dip coating and slush molding.
8. Study of injection molding of thermosets
9. Study of injection molding of DMC.
10. Study of compression and transfer molding of DMC.
11. Study of injection molding of thermoplastics.
12. Study of vented screw barrel systems.
13. Study of grooved barrel systems

Reference Books :

1. Thermosetting Plastics Practical Moulding Technology, **J.F. Monk** George Godwin Ltd, 1981.
3. Fundamentals of Polymer Processing, **Stanley Middleman,** McGraw-Hill, 1977.
4. Plastics Extrusion Technology Handbook, **James F. Carley,** Industrial Press Inc. 1989.
5. Plastics Engineering, **J. Crawford,**. Butterworth –Heinemann, [3rd edition], 2006
6. Polymer Extrusion, **Chris Rauwendaul,** Hanser Publication, Munich, 1987.
7. Polymer Processing, **Mcklevy J**., John Wiley, New York, 1962.
9. Applied Rheology in Polymer Processing, **B.R. Gupta**, Asian Book Pvt. Ltd, [1st edition] 2005.
10. Plastic Engineering Handbook of the society of the Plastics Industry, **Fredos J.** Van Nostrand Reinhold, N.Y. [4th edition].
11. Extrusion of Plastics, **Fisher,** Newnes - Butterworth, [3rd edition], 1976.
12. Engineering Principles of Plasticizing Extrusion, **Tadmor, Klein**, Krieger Publishing Company, 1978

309370 Polymer Rheology

Teaching Scheme				Examination Scheme		
Lectures	:	4 hrs./week		Paper	:	100 Marks/3 hrs.
Practicals	:	2 hrs./Week		T.W.	:	25 Marks
				Oral	:	25Marks
				Total	**:**	**150 Marks**

Objective

To study polymer melt flow behaviour and to bring out co-relation between polymer rheology and polymer processing

Section I

Unit I	**Introduction to Polymer Rheology**	**8 hrs.**

Introduction to Rheological Principles, Definition & importance of Rheology, types of fluids, Non Newtonian fluids, time-dependent fluids, time independent fluids, viscous elastic fluids, Pseudoplastic fluids, Dilatant fluids, Bingham plastic fluids.

Introduction to tensors, stress tensors and strain tensors, Basic equations of fluid mechanics - Continually equation, Couchy equation, Navier – stokes equation.

Normal stress difference and Weissenberg's effect.

Unit II	**Viscoelastic Behavior.**	**8 hrs.**

Stress relaxation, relaxation modulus, creep compliance dynamic modulus, dynamic compliance, dynamic viscosity, Mechanical models – Maxwell model, Voigt – Kelvin model, Zener model, Boltzmann Principle of Superposition.

Time-temperature correspondence, time-temperature superposition, WLF equation, Glass-transition and theories of glass transition - free volume theory, thermodynamic theory and kinetic theory. Molecular theories – Rouse theory, Doi – Edward theory, Curtis – bird model.

Unit III	**Parameters Influencing Polymer Rheology.**	**8 hrs.**

Effect of pressure on viscosity. Effect of temperature, activation energy, effect of molecular weight and molecular weight distribution on viscosity, molecular at dependence of zero shear viscosity, effect of crosslinking, crystallinity branching, copolymerization, effect of fillers, fiber filled polymer melts, effect of plasticizers, shear rate dependence of viscosity.

Section - II

Unit IV	**Melt Flow Analysis**	**8 hrs.**

Laminar flow through circular c/s, annulus, slit, parallel plates, irregular profiles. Flow analysis using power law, turbulent flow analysis, turbulence dumpling. Rheological models for extensional viscosity. Transition between laminar & turbulent flow, Ryan Johnson criterion, Application of Ryan Johnson criterion to power low fluids, extensional flow and rheological models for extensional viscosity.

Flow in coni-cylindrical dies – pressure drop due to shear, pressure drop due to extensional flow and pressure drop at die entry, flow in wedge shaped die. Swelling due to shear stresses and swelling due to tensile stresses.

Unit V	**Rheometry**	**8 hrs.**

Basic concept of constant stress & constant strain, Different types of Rheometers–Cone and plate Rheometer, Concentric cylinder rheometer, parallel disk rheometer, concentric rotating disk rheometer, controlled stress rotational Rheometer, Torque Rheometers – Extruder type.

Unit VI	Rheology in Polymer & Rubber Processing	8 hrs.

Rheology as applicable to following processes -

1 Injection molding.
2 Extrusion sheet : pipe, blown film etc.
3 Blown film extrusion.
4 Compression and transfer moulding.

List of experiments [any 08]

1. To study different types of fluids with examples.
2. To find M.F.I of different polymers using melt flow indexer.
3. To study the variation in viscosity with respect to temperature using capillary rheometer.
4. Fitting of rheological models using capillary rheometer [power low model, Ellis model etc.].
5. Estimation of Bagley's correction factor using capillary rheometer.
6. Study of cone and plate viscometer.
7. Study of Torque Rheometer.
8. Study of Brook field's viscometer.
9. Study of oscillating disc viscometers for rheological characterization of elastomers.

Reference Books :

1. Polymer Science & Technology **Premamony Ghosh,** Tata McGraw Hill Publication, [2nd edition,]. 1990.
2. Applied Rheology in Polymer Processing, **B.R. Gupta**, Asian Book Pvt. Ltd, [1st edition] 2005.
3. Polymer Melt Rheology, **F.N. Cogswell,** John Wiley and Sons, 1981, [1st edition].
4. Melt Rheology and its Role in Plastic Processing Theory and Applications, **Kurt F. Wissburn, Van Nostrand, Reinhold, John M. Dealy,** Chapman & Hall,1995.
5. Introduction to Polymer Viscoelasticity & Rheology, John .J**.** Aklonis, [2ndedition].
6. Principles of Polymer Processing, **John Wiley N.Y**. Tadmor Z. Gogos C.G.,A Wiley – Interscience Publication,1979
7. Injection Moulding Handbook, **Rosato and Rosato,** CBS Publishers & Distributors, 1987 [1st edition].
8. Injection Moulding Theory & Practice, **Irvin I. Rubin,** John Wiley .
9. Injection Moulding Materials, **E. Whelan,** Applied Science Publishers,1982
10. Polymer Mixing Technology, **George Matthews,** Applied Science Publishers, London,1982
11. Fundamentals of Polymer Processing**, Stanley Middleman,** McGraw Hill Education,1977
12. Plastics Engineering, **J. Crawford,** Butterworth –Heinemann, [3rdedition], 2006
13. Design Formulas For Plastic Engineers, **Natti. S. Rao**, Hanser Publishers,1999.

309371 SEMINAR
[T. E. Polymer Engineering 2008 Course]

Teaching Scheme:	**Examination Scheme:**
Tutorial: 2 Hrs / Week	Term Work: 50 marks

Engineering [preferably the advanced areas / application] and the topic should preferably be relevant to the curriculum.

It is expected that the student collect information from reference books, journals and Internet. The report submitted should reveal the student's internalization of the collected information.
Mere compilation from the net and other resources is discouraged.

Format of the Seminar report should be as follows:

1. The report should Seminar should be based on a detailed study of any topic related to Polymer be neatly written or typed on white paper. The typing shall be with normal spacing and on one side of the paper [A-4 size].
2. The report should be submitted with front and back cover of card paper neatly cut and bound or spirally together with the text.
3. Front cover: This shall have the following details.
    a. Title of the seminar report.
    b. The name of the candidate with roll number examination seat number at the middle.
    c. Name of the guide below the candidate's details.
    d. The name of the institute and year of submission on separate lines at the bottom.
4. Seminar approval sheet.
5. The format of the text of the seminar reports:

    The report shall be presented in the form of a technical paper. The introduction should be followed by literature survey. The report of analytical or experimental work done, if any, should then follow.

    The discussion and conclusions shall form the last part of the text. They should be followed by nomenclature and symbols used followed by acknowledgement. The bibliography should be at the end. References should be written in the standard format.
    The total number of typed pages, excluding cover shall be about 25 to 30 only. All the pages should be numbered. This includes figures and diagrams.

    Two copies of the seminar report shall be submitted to the college. The candidate shall present the seminar before the examiners. The total duration of presentation and after-discussion should be about 30 minutes. [25 min + 5 min]. Audience can ask questions only if the examiner permits. Such questions will not have any bearing on marks].

    The assessment for the subject shall be based on
    1. Report submitted.
    2. Presentation.
    3. Discussion.