FACULTY OF ENGINEERING

Syllabus for the

B.E. (Polymer Engineering) 2012 Course

(w. e. f. 2015-2016)

SAVITRIBAI PHULE PUNE UNIVERSITY

Savitribai Phule Pune University
Structure of BE Polymer Engineering (2012) Course

SEM - I										
Code	**Subject**	**Teaching Scheme H/Week**			**Examination Scheme**					**Marks**
		LECT	**PR**	**DR**	**In-Semester Assessment**	**TW**	**PR**	**OR**	**End-Semester Exam**	
409361	Polymer Materials & Compounding	4	2	--	30	25	--	--	70	125
409362	Mold & Die Design	4	--	2	30	--	--	50	70	150
409363	Polymer Processing Operations	4	2	--	30	--	50		70	150
409364	Elective I	3	--	--	30	--	--	--	70	100
409365	Elective II	3	--	--	30	--	--	--	70	100
409366	Project Phase I	--	--	2	--	50	--	--	--	50
409367	Industrial Training Evaluation	--	--	--	--	50	--	--	--	50
409368	Introduction to Polymer Industries I	--	--	--	--	25	--	--	--	25
	Total (26 Hrs)	18	4	4	150	150	50	50	350	750

SEM - II										
Code	**Subject**	**Teaching Scheme H/Week**			**Examination Scheme**					**Marks**
		LECT	**PR**	**DR**	**In-Semester Assessment**	**TW**	**PR**	**OR**	**End-Semester Exam**	
409369	Advanced Polymer Rheology	4	2	--	30	--	--	50	70	150
409370	Product Design &Polymer Testing	4	2	--	30	25	50	--	70	175
409371	Elective III	3	--	--	30	--	--	--	70	100
409372	Elective IV	3	--	--	30	--	--	--	70	100
409373	Computational Tools in Design and Simulation	--	2		--	50	--	--	--	50
409374	Project Phase II	--	--	6	--	50	--	100	--	150
409375	Introduction to Polymer Industries II	--	--	--	--	25	--	--	--	25
	Total (26Hrs)	14	6	6	120	150	50	150	280	750

ELECTIVES			
Elective I	**Elective II**	**Elective III**	**Elective IV**
1. Polymer Reaction Engineering	1. Specialty Polymers & Applications	1. Polymer Physics and Characterization	1. Polymer Nanotechnology
2. Surface Coating Technology	2. Entrepreneurship and Management	2. Polymer Thermodynamics and Blends	2. Polymers in Advanced Applications
3. Composite Technology	3. Advanced Polymer Science	3. Elastomer and Rubber Technology	3. Polymer Waste Management

SEMESTER I

409361 : Polymer Materials and Compounding

Teaching Scheme:
Lectures: 4 h/week
Practical: 2 h/week

Examination Scheme:
In Semester: 30
End Semester: 70
TW: 25
Total: 125

Objective
To impart the knowledge of mixing, blending and compounding processes of various additives in the polymer to get the desired formulation and to study various mixing devices from the point of view of optimization.

Unit I: Polymer Mixing and Blending (8h)
Introduction, mechanism of mixing and dispersion, mixing of solid-solid, liquid-liquid and liquids-solids, dispersive mixing, distributive mixing and laminar mixing, mixing entropic measures and its applications, mixing indices, kinetics of mixing, rheology of filled polymers, overview of polymer mixing and blending machinery.

Unit II: Compounding (8h)
Introduction, types and characteristics of compounds – polymer blends, polymer formulations, filled polymers and polymer composites, compounding practice, mixing types, solid additives, morphology of filler additives, filler reinforcement, compatibilizers – mechanism and theory, surface modification and interfacial agents, dispersion of polymer nanoparticles in polymer melt. Master batches, color theory.

Unit III: Polymer Compounds (8h)
Polymer compound ingredients, fillers and reinforcements viz. carbon black, calcium carbonate, titanium oxide, nano clay, glass fibers, organic fillers, nanofillers, processing aids, flame retardants, etc., multi-component compounds, compounding of polyolefins, polystyrene and styrene copolymers, engineering polymers, natural ingredient filled plastics, compounding lines, post compounding operations.

Unit IV: Mixing and Compounding Applications (8h)
Additives used for plastics, inorganic filler compounding, glass fiber compounding, nano-composite compounding, recycling applications, reactive blending and compounding, free radical grafting of monomers onto polymers, elastomer compounding (NR, SBR, BR, IR, EPDM etc.), compounding materials used for unsaturated polyester, mixing and compounding of PVC, compounding practices for other polymers, compounding for cable and profile extrusions, compounding economics.

Unit V: Mixing Machinery and Devices (8h)
Batch and internal mixers, single screw extruder, kneaders, modular co-rotating and counter-rotating twin screw extruders, continuous mixers, co-kneader, mixing mechanisms, modeling of kneader, residence time distribution, feeding and feeder, distributive mixing sections, cavity mixers, pin mixers, slotted fight mixers, variable depth mixers, blister ring, fluted mixing section, planetary gear mixers, CRD mixers.

Unit VI: Compounding Machinery and Devices (8h)

Two roll mills: Design features, speeds & friction ratios, sizes & capacities, mixing action, strip cutting, cross mixing devices. Internal mixers: Design features, rotor designs, control. Single screw compounding machine: Two section screws, smear–heads, screws with kneaders, shear cone units, barrels with internal projections. Twin screw extruders: tapered screws in feed zone, internal mixer zones, and continuous internal mixer. Intermeshing corotating, corotating geometry, conveying characteristics of screw elements & mixing elements, metering zone, leakage flow equations, solids conveying zone, melting mechanism, residence time distribution.

List of Practical (Expt. no. 1 is compulsory plus any 8 form 2 to 14):

1. Introduction to operating characteristics, machine construction, specifications, process control systems and working details of various batch and continuous mixers and other equipments. (compulsory experiment)
2. To study the functioning of two roll mill.
3. To study Banbury mixer.
4. Mixing characteristics of sigma mixer and preparation of Dough Molding Composition formulations using sigma mixer.
5. Preparation of plasticized polyvinyl chloride (PVC) compound using two roll mill.
6. Preparation of phenolic molding compound using two roll mill.
7. To study the mixing time for compounding of plasticized PVC compositions by using *Brabander.*
8. To study the torque and mixing time for compounding of filled (Talc and $CaCO_3$) polypropylene compositions.
9. Preparation of plasticized PVC compound using single screw extruder.
10. Preparation of filled polymers using twin screw extruder.
11. To study power consumption for twin screw compounder.
12. Preparation of master batch – for PVC based cable application.
13. To study compounding and dispersion of carbon black filled compositions.
14. Compounding of rubber

Reference Books:

1. "Unit operations in Chemical Engineering", Mccabe ,Smith & Harriot, McGraw Hill, 1993
2. "Mixing in polymer processing "- Edited by Chris Rawendaal, Marcel Dekker.
3. "Principles of Polymer Processing", Second Ed., Z. Tadmor, C.G. Gogos, Wiley-Interscience, 2006.
4. "Advanced polymer processing operations", edited by Nicholas P. Cheremisinoff, Noyes publications, 1998.
5. "Polymer mixing and extrusion", Nicholas Cheremisinoff, Marcel Dekker, 1998
6. "Polymer mixing technology", George Mathews , Applied science, London,1984
7. "Plastics Materials", J. A. Brydson, Jordon Hill, Oxford, 1999.
8. Polymer Mixing Technology and Engineering, J.L. White, A.L. Coran and A. Moet, HanserGardner Publications Ltd., USA, 2001.
9. Rubber Technology Compounding and Testing for Performance, Ed. J. S. Dick, HanserGardner Publications Ltd., USA, 2001.
10. Thermoplastic and Rubber Compounds Technology and Physical Chemistry, J.L. White, K. – J. Kim, Hanser Gardner Publications Ltd., USA, 2007
11. Mixing and Compounding of Polymer Theory and Practice, 2nd Ed., I. M. Zloczwero, Hanser publications, 2009
12. Understanding Compounding, R. H. Wildi and C. Maier, Hanser Gardner Publications Ltd., USA, 1998.

409362: Mold and Die Design

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 h/week	In Semester: 30
Drawing/Pr: 2 h/week	End Semester: 70
	OR: 50
	Total: 150

Objective:

To impart the knowledge of injection mold and extrusion die design so that when the students join the industry, they are fully acquainted with design aspects like design calculations, assembly, detailing of molds as well as mold materials and manufacturing aspects.

Unit I: Constructional features of basic mold and its elements (8 h)

Types of - locating rings, guide pillars, guide bush, spigotted guide pillars and guide bush; Design features of standard mold components, materials used for mold bolsters, inserts, standard mold parts, manifold, gears, splits, wear plate, heel block, lead screw, injection molding machine specifications, clamping tonnage and shot weight estimation, calculations for number of cavities based on clamping tonnage, shot weight, machine platen size, calculations for cavity pressure. Feed system: Constructional features and types of sprue bush, types of runners, runner layout, calculation of runner efficiency, runner design; types of gates, gate design calculations, runner and gate fabrication techniques, runner balancing calculations.

Unit II: Cooling, hot runner and ejection System (8 h)

Cooling system: Bolster cooling systems, insert cooling systems, baffle, bubbler cooling systems, heat rod and heat pipe systems, cooling time calculation, cooling channel layout. Hot runner mold, design of hot runner block, types of manifold blocks rectangular and circular, types of secondary nozzles, heating systems used, manifold heating capacity calculations and expansion calculations. Ejection system: Ejector assembly, ejector assembly return systems, ejector grid layout, types of ejectors; stripper plate ejection technique; types of spare pullers, calculation of ejector force.

Unit II: Design and constructional features of molds (8 h)

Design and constructional features of two plate moldunderfed mold, split and side core molds. Actuation techniques: finger cam, dog leg cam, cam-track actuation, split movement calculations, split safety techniques. Design and constructional features of injection mold, compression mold, transfer moldextrusion blow mold, injection stretch blow mold, thermoforming,rotational molding.

Unit III: Die Design (8 h)

Classification of dies and die geometry, types of dies, extrusion die design: basic considerations in die design; constructional and design features of rod die, in-line pipe die, cross-head pipe die, offset pipe die, centre-fed blown film die, side-fed blown film die, spiral mandrel blown film die, flat film& sheet dies, fishtail sheet die, coat hanger sheet die, wire and cable coating die, parison dies, various types of profile dies.

Unit IV: Heat Treatment, Finishing Operations and Metrology (8 h)

Basic tools and die materials, BIS and other major coding systems, materials, effect of alloying, various heat treatments, surface hardening, cutting tool geometry, mold fabrication techniques like spark erosion, milling, finishing operations, super finishing, costing of molds and mold maintenance; metrological aspects of moulds, terminology, ISO system of limits and fits, tolerance,geometric characteristics and symbols.

Unit VI: Advanced Mould Design and Flow Analysis **(8 h)**
Molds for internally and externally threaded components, thread profile, fixed and loose threaded cores, collapsible core, stripping, ejection, power and transmissions systems, design calculations for the gears. CAD/CAM/CAE applications in mould design: basic concepts, two dimensional drafting, 3D modeling, application examples, computer aided die and mould manufacture. Understanding of flow analysis by simulation and its use for injection mold design, constitutive equations for flow analysis, modeling for flow analysis, optimum gate locations, pressure drops across runner, gate, fill analysis, packing profile analysis, shrinkage and warpage, introduction to finite element analysis.

List of Practical:
1. Design and drawing of at least three sheets for the following:

a. Multi cavity two plate molds
b. Multi cavity underfed molds
c. Dies for pipe and blown film

2. Mold fabrication practical - manufacture and assembly of a simple mold which includes the manufacture of standard mold parts like guide pillars, guide bush, sprue bush, locating ring etc.

Reference Books:

1. Fundamental of Plastic Moulding Design**,** S K Nayak, P C Padhi, Y Hidayathullah, Tata McGraw-Hill Education
2. Computer-aided Injection Mold Design and Manufacture, J.Y.H. Fuh, M. W. Fu, A.Y.C. Nee, Y F Zang, CRC Press, 2004.
3. How to make Injection Molds – Menges and Mohren, Hanser publication Munich Vienna New York, second edition, 1986.
4. Dies for Plastics Extrusion - M.V. Joshi, Macmillan India Ltd., first published in 1984.
5. Plastic Molds and Dies by Sors, Bardocz, Radnoti, Publisher: Von Nostrand Reinhold Company and Akademiai Kiado, 1981
6. Mold Engineering by Herbert Rees, Hanser Publishers, Munich Vienna N.Y.,1995
7. Plastics Mold Engineering Handbook by J. Harry Drebois and Wayne I. Prible, publisher: Von Nostrand Reinhold N.Y., 1987.
8. Fundamentals of Injection Moulding Design, A B. Glenvil L and Denton
9. Machine Tool engineering, G. R Nagpal, Khanna Publishers, 2004
10. Engineering Metrology, R. K. Jain, Khanna Publishers, 2007
11. Injection Mold Design - R.C.W. Pye, fourth edition, East-west press pvt.ltd publication.
12. Molding machine and mold for plastic processing, Negri Bossi, second edition, 1987, publisher: Negri Bossi Spa, 1984

409363: Polymer Processing Operations

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 h / week	In Semester: 30
Practical: 2 h / week	End Semester: 70
	PR: 50
	Total: 150

The subject prepares the student for understanding of various polymer processing operations from process control and processing equipment point of view. The subject deals with basic processes like blow molding, thermoforming, calendaring. The subject also imparts the knowledge of post moulding operations like printing and other decorative methods.

Unit I: Blow Moulding (8 h)

Blow moulding– Fundamentals of the process, complete blow moulding operation, accumulator based machines, extrusion blow moulding (continuous, intermittent), injection stretch/orienting blow moulding, Blow moulding machines, start-up and shut-down procedures, process control, blow molding plants, partisan programming, cutting devices, process parameters and their effect on product quality control, moulding defects - causes and troubleshooting.

Unit II : Thermoforming (8 h)

Thermoforming– Basic process, thermoforming machines and plants, thermoforming materials, analysis of sheet heating, stretching and wall thickness distribution, simple vacuum forming, drape forming, air-slip forming, pressure forming, drape forming, blister forming, solid-phase pressure forming, plug-assist forming. Process factors in thermoforming, overtation and heat reversion, defects in thermoformed articles and troubleshooting, equipment details.

Unit III: Calendaring (8 h)

Calendaring - Basic process, material and products, calendaring plant, types of calendars, roll construction, roll configurations, drives, heating system, film and sheet lines, laminating and embossing lines, various parameters, control and their effect on quality, defects, causes and remedy. Calendaring lines – General purpose line, pre-calender and post-calender train, special lines and arrangements, calendared flooring lines, lamination with calender. Analysis of calendaring – (through put), pressure profile through the calendar, flow and pressure generation at calendar nip, roll separation forces and methods of compensation, roll bending, roll deflection, methodologies to take care of roll bending & deflection, sheet gauge thickness control.

Unit IV: Rotational Moulding (8 h)

Rotational moulding - Basic process, materials and product parameters, temperature, speed, cooling, effect on product quality, control system, bubble formation of rotational molding, methods of bubble removal, effect of internal pressure in rotational molding, multilayer rotational moulding, rotational moulding of nylon, polyethylene etc., rotational moulding of liquid polymer. Rotational moulding equipment, drive, batch type and continuous type machines. Rotational moulding process analysis - mould temperature rise, heat and melt flow in rotational moulding, cycle time calculations.

Unit V: Non-Conventional Injection Moulding (8 h)

Microstructure development in slow crystallizing and fast crystallizing polymers, molecular orientation, effect of crystallinity on material properties, volumetric and anisotropic shrinkage, weld lines and methods of removal of weld lines. Gas injection moulding – types, process modeling, gas dissolution, gas fingering, unstable gas penetration, water injection moulding, classification of different water injectors, injection foam moulding-types, microcellular injection foam moulding, nucleation and pressure profiles during filling, powder metal injection moulding - process and steps involved, microinjection moulding - types and process details, reactive injection moulding.

Unit VI: Machining, Printing, Decoration Methods and Recycling (8 h)
Machining: special guidelines for machining of polymers with respect to tool geometry and other machining parameters. LASER machining. Printing: printing equipments used for on-line printing and batch printing, study of various machines, types of inks used, and printing techniques for plastics products. Decorating methods: surface preparation, electroplating, vacuum metalizing, texturising, special effects like rainbow effect, hot stamping, embossing. Recycling of plastics: typical equipments used for recycling.

List of Practical (any eight):

1. Vacuum and plug assisted thermoforming of HIPS, ABS, PP.
2. Study of effect of processing parameters on thermoforming product.
3. Extrusion blow moulding of PP/HDPE/PVC.
4. Study of injection stretch blow molding of PET.
5. Study of effect of process parameters on blow moulding.
6. Rotational moulding of various materials.
7. Effect of process parameters (temperature, speed ratio of the two axes, cooling, etc.) on the quality of a rotationally molded product.
8. Demonstration & study of screen printing on plastics.
9. High frequency welding of PVC and study of other methods of welding.
10. Machining of plastics. (e. g. acrylics, PVC etc.)
11. Rotational moulding of liquid polymers.
12. Study of decorative methods for plastics.
13. Manufacture of PU foam by reaction injection molding.

Reference books:

1. Blow Molding Handbook, Ronald Rosato & Dominick Rosato, Hanser Publication, 1989.
2. Applied Rheology in Polymer Processing, B.R. Gupta, Asian Book Pvt. Ltd, (1st edition) 2005.
3. Injection Moulding- Technology and fundamental, Musa R Kamal, Avraaam I Isayev, Shih-Jung Liu, Series editor James L White, Hanser Publishers, Munich, 2009
4. Polymer Processing, Mckelvy J., John Wiley, New York, 1962.
5. Fundamentals of Polymer Processing, Stanley Middleman, McGraw-Hill, 1977.
6. Rotational moulding , R. J. Crawford, Research Press Ltd, 1996
7. Plastic Engineering Handbook of the Society of the Plastics Industry, Frados J. Van Nostrand Reinhold, N.Y. (4th edition).
8. Plastics Engineering, R J. Crawford, Elsvier Publish (3rd edition), (1998), Indian print-2006
9. Technology of Thermoforming - J.L. Throne Hanser Gardner Pub. Inc, 1996
10. Plastics: Surface and Finish; Edited by: S. H. Pinner, W.G. Simpson; London Butterworth, 1971
11. Calendaring of plastics - R.A. Elden, A.D. Swan London Iliffe books., 1971
12. Plastic Waste Management – Disposal, Recycling and Reuse, Nabil Mustafa, Marcel Dekker Inc, 1993

Elective I

409364 (1) : Polymer Reaction Engineering

Teaching Scheme:
Lectures: 3 h/week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Objective

To understand the polymerization reactions mechanism and their effect on the design of polymerization reactors. To understand the distinguishing features as well as the challenges involved in polymer manufacturing processes as compared to monomer manufacturing processes. To get acquainted with technologies used for manufacturing polymers at commercial scale.

Unit I: Introduction (7h)

Introduction to macromolecules and polymer reaction engineering, fundamental concepts, classifications of polymers based on polymerization mechanisms, study of molecular weight distribution, distinctive features of polymers and polymerization reactors as compared with monomers and their reactors, studies on changes in viscosity, density and rate constant with conversion.

Unit II: Kinetics of Polymerization (7h)

MW/MWD obtained for chain-growth, step-growth polymerization in batch reactor, plug-flow reactor (PFR) and continuous stirred tank reactor (CSTR), kinetic studies of cationic, anionic and free radical polymerization reactions. Ziegler-Natta catalyst in stereo-regular polymerization, kinetics mechanism in heterogeneous and stereo-regular polymerization reactions, rates of Ziegler-Natta polymerization, average chain length of polymer in stereo-regular polymerization.

Unit III: Kinetics of Suspension and Emulsion Polymerization (7h)

Introduction to bulk, solution, suspension and emulsion polymerization techniques, aqueous emulsifier solution, kinetic aspects of suspension and emulsion polymerization (Smith-Ewart Model), determination of total number of particles, molecular weight in emulsion polymerization, emulsion polymerization in homogenous CSTR, kinetics of dispersion polymerization.

Unit IV: Polymerization Reactor (7h)

Descriptive account of reactor systems used for the following polymers – polyvinyl chloride, polystyrene, polyethylene terephthalate, nylon-6, nylon-66, styrene-butadiene rubber, polypropylene, polyethylene,interpretation of reactor data.

Unit V : Kinetics at High Degree of Conversion (7h)

Verification of the kinetic model and the gel effect in radical polymerization, equilibrium of radical polymerization, temperature effects in radical polymerization, role of inter phase mass transfer in the selection and the design of polymerization reactor (especially step-growth polymerization reactors), diffusional effects in Ziegler-Natta polymerization, and metallocene catalyst for olefin polymerization.

Unit VI: Reactor Selection and Control Considerations (7h)

Basic factors in reactor design, reactor selection, phase selection and reactor operations, role of various process, variables and related instrumentation, qualitative account of control engineering considerations in operation of batch and continuous polymerization process.

Reference Books:

1. Anil Kumar and R.K. Gupta, "Fundamentals of Polymer Engineering", 2^{nd} edition, Marcel Dekker, 2003.
2. Neil A. Datson, Rafael Galvan, Robert L. Laurence and Mathew Tirrel, "Polymerization Process Modeling", VCH Publishers, Inc., 1996.
3. F. Joseph Schork, Pradeep B. Deshpande and Kenneth W. Leffew, "Control of Polymerization Reactors", Marcel Dekker, 1993.
4. Gupta S. and Anil Kumar, "Reaction Engineering of Step Growth Polymerization", Plenum Press, New York, 1987.
5. "Encyclopedia of Polymer Science and Engineering", 2^{nd} edition, John Wiley & Sons, 2005.

Elective I

409364 (2) : Surface Coating Technology

Teaching Scheme:	**Examination Scheme:**
Lectures: 3 h/week	In Semester: 30
	End Semester: 70
	Total: 100

Objective

To introduce the student to various basic concepts and various aspects of ingredients, manufacture, testing and applications of coating materials.

Unit I: Theory of Surface Coating and ingredients (7 h)

Definitions and general classification of paints, varnishes and lacquers, mechanism of film formation, oil types, chemical properties of oils, introduction to pigments & dyes, organic and inorganic pigments, fillers and additives - dispersing agent, emulsifier, anti settling agent, biocides, antifoams, corrosion inhibitors, U.V. and light stabilizers, antioxidants, driers, solvents, properties of solvents, water as coating solvent, various steps in paint manufacture, phenomenon of mixing.

Unit II: Natural Resins and Polymers (7 h)

Natural resins and polymers - rosin, shellac, natural bitumen and asphalts gilsonite, petroleum bitumen, bituminous paints, pitches, gums, glues, casein, cellulosic polymers, rubber resins.Synthetic polymers - application and some important aspects of the following resins - alkyd, polyester, phenolic, amino, epoxy, polyamide, polyurethanes, silicone, acrylic and vinyl resins etc.

Unit III: Formulations and Coating Properties (7 h)

Typical formulations, general properties of paints, varnishes and lacquers, adhesion and cohesion properties, factors affecting adhesion, wetting power, physical, chemical and mechanical properties of paint films, objectives of paint testing, standard specifications and test methods, test on liquid paints, density, dispersion, viscosity, consistency, spreading capacity, wet opacity, dry hiding, spreading time, drying time, etc., optical properties- color, gloss, haze & clarity, opacity, orange peel, transparency, hiding power, mechanical properties, environmentalresistance and ageing properties,modern computerized methods of colour matching.

Unit IV: Grinding and Manufacturing Process (7 h)

Paint manufacturing machinery for pigment dispersion (ball mill, sand mill, attritor mills, Drais mill, basket mill, kaddy mills, twin shaft dispenser, alpine mills, horizontal V/S verticalmills. Manufacture of powder coatings, dry distempers, cement paints, oil based distempers and paints, other stiff paints, putties, manufacturing of alkyds, emulsions and hard resins, filtration of resins, paints, ultra filtration of ED resins, forming of hard resins, solvent emission, recovery and disposal, plant layout, inter-phasing with R&D, environmental, health and safety issues.

Unit V: Advanced Paint Technology (7 h)

Paints for marine environments, vinyl paints, road marking paints, cement paint, automotive protection products & paints, electro-deposition coatings, UV curable coatings, coatings for high temperature, coatings for aerospace and aircrafts, electrical conducting coatings, thermal sensitive paints, insulating paint, metallic paints, coatings for plastics and paints: Formulating Plastics for Paint Adhesion, special effect pigments (IR reflective, anticorrosive, thermo chromic, pearlescent etc), in-can corrosion preventer, nano-coatings: nano ingredients, advantages, end application.

Unit VI: Evaluation of Paint **(7 h)**

Evaluation of physical properties of paints, varnishes and lacquers, density bulking value by wt/ litre cup, non-volatile matter, fineness of grind by Hegman gauge, viscosity by Brookfield, bubble tube and cone & plate viscometer, application of films by automatic film applicator and bar applicator, determination of wet film and dry film thickness, drying time, surface roughness, evaluation of optical properties, mechanical Properties, electrical resistance properties, weatherometer tests, modern instrumentation techniques in paint and coatings.

Reference Books:

1. Organic Coating Technology, Volume I, by Henry Fleming Payne, John Wiley & Sons, 1954.
2. Surface Coatings, Volume I, by OCCA Australia (Prepd.), Chapman and Hall, 1983.
3. Outlines of Paint Technology, III Ed. By W. M. Morgans, Edward Arnold, 1969
4. Surface coatings: Science and Technology, by Swaraj Paul, John Wiley and Sons, 1985
5. Organic Coatings: Science and Technology, Volume I, by Z. W. Wicks, F. N. Jones and S. P. Pappas, Wiley-Interscience, 2007.
6. Basics of Paint Technology, Part I & II, by V. C. Malshe & Meenal Sikchi, 2002.
7. Datta P.K. & Gray J.S. Surface Engineering Vol.I, II and III Fundamentals of coatings.Royal Society of London, 1993.
8. William Hannum, Grubb Bullard, Naval electrician’s text book volume 1, Nabu Press, 2012.
10. Rose A. Ryntz, Philip V. Yaneff Coatings of Polymers And Plastics, CRC Press, 04-Feb-2003

Elective I

409364 (3) : Composite Technology

Teaching Scheme:
Lectures: 3 h/week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Objective
To understand the mechanical behavior of composites so as to prepare the students for undertaking design of composite products and understand micromechanics through lamination theory and to understand the various processes of manufacturing techniques from process control, process design and tooling point of view and to acquaint students with properties of different types of matrix materials and reinforcements.

Unit I: Introduction to Composite Materials (7 hrs)
Advantages and applications of composite materials, properties and applications of various types of glass fiber, carbon fibers, aramide fibers, polyethylene fibers, boron fibers, ceramic fibers, natural fibers. Matrix material - thermoset matrix materials like - epoxy, polyester, vinyl esters, phenolic resin, polyimides, degree of cure, gel time test, thermoplastic matrix materials like - polyolefins, polyether ether ketones, polyphenylene sulfide, thermoplastic polyimides, high performance resin matrix. Interface of polymer matrix composites. Processes: prepreg lay-up, wet lay-up, spray up, roll wrapping process, moulding and forming methods of composite materials, sheet moulding compounds, bulk moulding compounds, metal matrix composites, ceramic matrix composites.

Unit II: Macromechanical Vs Micromechanical Behavior of a Lamina (7 hrs)
Stress-strain relations for anisotropic materials, stiffness compliances and engineering constants for orthotropic materials, restrictions on engineering constants, stress-strain relations for plane stress in an orthotropic material, stress-strain relations for a lamina of arbitrary orientation, invariant properties of an orthotropic lamina, experimental determination of strength and stiffness, orthotropic biaxial strength criteria, mechanics of materials approach to stiffness, elasticity approach to stiffness, comparison of approaches to stiffness, mechanics of materials approach to strength.

Unit III: Macromechanical Behavior of a Laminate (7 hrs)
Classical lamination theory, special cases of laminate stiffnesses, laminate code, symmetric laminates, anti-symmetric laminates, non-symmetric laminates, balanced laminates, quasi-isotropic laminates, theoretical and experimental cross-ply laminate stiffness and angle-ply laminate stiffness.

Unit V : Design of Composite Structures, Vibration and Testing (7 hrs)
Introduction to structural design, steps, design analysis, failure analysis, material selection factors, design of - sandwich structures, tension members, compression members, torsional member, beam, laminate joints.Optimization concepts, analysis of laminated plates and beams - bending, buckling and free vibrations: first order shear deformation, higher order shear deformation theory, governing vibration equations for laminated beam. Various tests for compressive and tensile properties - fixtures and methods, three point and four-point bending, shear test methods, fatigue tests, pin bearing properties, damage identification using nondestructive evaluation techniques: ultrasonic, acoustic emission, X-radiography, thermography, laser shearography.

Unit III: Autoclave, Resin Transfer and Pultrusion (7hrs)

Autoclave processing: Resin viscosity and kinetic models in autoclave processing, void models and theory of void formation in autoclave processing, liquid composite molding like resin transfer molding, structural reaction injection moulding: Preforming, mold filling, cure and mould design considerations. Pultrusion: Process description, pultrusion of thermoplastics – matrix composites, matrix flow, pressure and pulling resistance modeling of pultrusion process, composites.

Unit V: Filament Winding and Joining Techniques (7 hrs)

Filament winding: Process of filament winding, winding techniques, equipment, process models like – thermo-chemical sub-model, fiber motion sub-model, consolidation sub-model, stress sub-model, void sub-model, applications of filament winding, thermoplastic tape winding. Joining techniques - Various types of bonded joint configurations, adhesive joints, failure modes in adhesive joints, mechanical joints, machining of composites, water jet cutting, laser cutting.

Reference Books:

1. Polymer Matrix Composites and Technology, R, Wang, S, Zheng, Y. George Zheng, Woodhead Publishing Limited, 2011.
2. Mechanics of Composite Material, Robert Jones, McGraw hill company,
3. Fibre Reinforced Composites, P. K. Malik, Marcel Decker, 1988.
4. Mechanics of Composite Materials, Autar K. Kaw, CRC press, Boca Raton, New York, 1997
5. Analysis and Performance of Fiber Composites, 3rd edition, Bhagawan D. Agarwal, Lawrence J. Broutman, K. Chandrashekhara, John Wiley & Sons Inc, 2006
6. Processing of composites, R. C. Dave, A. C. Loos (Editors), Hanser publications, 2000.
7. Composites Manufacturing : Materials, Product, and Process Engineering, Sanjay K Mujumdar, CRC press, 2002
8. Fibre-glass Reinforced Plastics, N. P. Cheremisinoff (Ed), Noyce Pub. 1988.
9. Design Data for Reinforced Plastics, N. L. Hancex, R. M. Mayer, Chapman Hall, 1994
10. Reinforced Plastics: Properties and Applications, Raymond Seymour, The Materials Information Society, 1991.
11. Clay containing Polymeric nano-composites, Volume 1, L.A. Utracki, RapraTechnology Limited, 2004
12. Nano-composites: Preparation, Properties and Performance, Lorenzo H Mancini and Christian L Esposito (editors) Nova Science Publications Inc, New York, 2008
13. Nano structured materials: Processing, Properties and Applications, Carl C Koch, William Andrew Publishing, 2007
14. Processing and Properties of Nano-composites, Suresh G Advani, World Scientific Pub. Co. Pvt. Ltd, 2007
15. Handbook of Polymer Composites for Engineers, Ed. Leonard Hollaway, Woodhead Publishing, 1994

Elective II

409365 (1) : Specialty Polymers and Applications

Teaching Scheme:	**Examination Scheme:**
Lectures: 3 h/week	In Semester: 30
	End Semester: 70
	Total: 100

Objective

To familiarize the students with a specific class of advanced polymers defined on the basis of their specific properties. This paper will emphasize on the study of property correlation with various aspects and processing requirements for specialty polymers, engineering and specialty application of these materials in various vital fields like high performance applications, biomedical, aerospace engineering, electronics and other areas.

Unit I: Liquid Crystalline Polymers (LCPs) (7h)

Introduction, history, structural requirements, types of liquid crystalline (LC) phases, types of liquid crystalline polymers, anisotropic properties, characterization of LC phases (DSC, POM, XRD, NMR, FTIR, Dielectric etc.), LC blends and composites, LC elastomers, rheology of liquid crystalline polymers, applications of LC polymers- optical, high strength fibers, MEMS etc.

Unit II: Conducting Polymers (7h)

Theory of conduction, semi conductors and conducting polymers, band theory, requirements for polymer to work as conductor, types of conducting polymers - intrinsic and extrinsic, doping of polymeric systems, synthesis, processing and testing of conducting polymers, applications and recent advances – electroluminescence, corrosion inhibition, microelectronics, membranes, sensors, textiles, elecrochemomechanical devices, coating etc..

Unit III: Heat and Fire Resistant Polymers (7h)

Combustion of polymeric materials and methods to reduce it, requirements for heat resistance, determination of heat resistance, synthesis, structure-property relationships, fire retardant fillers, applications of heat resistant polymers like polyamides, polyimides and its derivatives, polyquinolines, polyquinoxalines, PBT, PBO, PBI, PPS, PPO, PEEK, chlorinated polymers, engineering plastic blends.

Unit IV: Smart Polymers (7h)

Introduction to smart polymers, temperature responsive polymers, pH responsive polymers, photo responsive polymers, magnetically responsive polymers, enzyme responsive polymers, shape memory polymers, hydrogels, self-healing polymers. Applications of smart polymers in various fields such as drug delivery, tissue engineering, medical devices, bioseparation, optical data storage, packaging and textiles etc.

Unit V: Biopolymers and Biodegradable Plastics (7h)

Biopolymers **-** Study of biopolymers and their applications, like bioassays, biocatalysts, etc., need of biomaterials and biopolymers, biodegradation, overview of biodegradable polymers, degradation study, factor affecting biodegradability, classification – natural, synthetic, modified, starch based, PHAs, PLA, synthetic biodegradable polymers- PBS, PCL, PGA, etc., environmental impact, biomaterials and their medical applications, control release theory, scaffold materials, orthopedic applications, rehabilitation aids, etc., ASTM methods of testing.

Unit VI: Miscellaneous Polymers (7h)

Macromolecules as catalysts, information transmitting polymers, reactive polymers, magnetic polymers, luminescent polymers, ion conducting polymers, high performance fibers, dendritic polymers, inorganic polymers, ionic polymers, hydrogels.

Reference books:

1. Polymers for High Technology Electronics and Photonics; M.J. Bowden and S.R. Tumer, Amer. Chem. Soc., 1987
2. Recent Advances in Liquid Crystalline Polymers; L. Lawrence Chapoy, Ed. Elsevier Science, New York, 1985
3. Engineering Polymers; R.W. Dyson, Chapman and Hall, New York, 1990
4. Additive for coatings, John Bieleman, Wiley-VCH, 2000
5. Additives in waterborne coatings, Gerry Davison, Bruce Lane, Royal society of Chemistry, 2003
6. Encyclopedia of Polymer science and Engineering Vol.1-17, Jacqueline I. Kroschwitz, 2007.
7. Modern Biopolymers science: Bridging the divide between fundamentals treatise and industrial application, Stefan Kasapis, Ian T. Nortan, Johan B Ubbink, Elsevier Inc., 2009.
8. Fire Properties of Polymeric Composites Materials, A.P. Mouritz, A G. Gibson, Springer, 2006.
9. Specialty Polymers: Materials and Applications, Ed. Faiz Mohammad, I. K. International Pvt Ltd, 2007
10. An Introduction to Speciality Polymers, Norio Ise, IwaoTabushi, CUP Archive, 1983
11. Liquid Crystal Polymers: Synthesis, Properties and Applications, Ed. D. Coates, iSmithersRapra Publishing, 2000.
12. Handbook of Conducting Polymers, Second Edition, Ed. Terje A. Skotheim, CRC Press, 1997.
13. Smart Polymers and their Applications, Ed. Maria Rosa Aguilar, J.S. Román, Woodhead Publishing, 2014.

Elective II

409365 (2) : Entrepreneurship and Management

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Objective:
To introduce the students with their inherent skills pertaining to entrepreneurship and industrial management. To make them aware of the good attributes of an entrepreneur / manager. Also to introduce the student with various initiatives and facilities provided by the government to start an enterprise or a small scale industry.

Unit I: The Entrepreneurial Development Perspective (7h)
Concepts of Entrepreneurship Development, Evolution of the concept of Entrepreneur, Entrepreneur Vs. Intrapreneur, Entrepreneur Vs. Entrepreneurship, Entrepreneur Vs. Manager, Attributes and Characteristics of a successful Entrepreneur, Role of Entrepreneur in Indian economy and developing economies with reference to Self-Employment Development, Entrepreneurial Culture.

Unit II: Creating Entrepreneurial Venture and Project Management (7h)
Business Planning Process, Environmental Analysis - Search and Scanning, Identifying problems and opportunities, Defining Business Idea, Basic Government Procedures to be complied with, Technical, Financial, Marketing, Personnel and Management Feasibility, Estimating and Financing funds requirement - Schemes offered by various commercial banks and financial institutions like IDBI, ICICI, SIDBI, SFCs, Venture Capital Funding.

Unit III: Entrepreneurship Development and Government (7h)
Role of Central Government and State Government in promoting Entrepreneurship - Introduction to various incentives, subsidies and grants, Fiscal and Tax concessions available, Role of following agencies in the Entrepreneurship Development - District Industries Centers (DIC), Small Industries Service Institute (SISI),Entrepreneurship Development Institute of India (EDII), National Institute of Entrepreneurship & Small Business Development (NIESBUD), National Entrepreneurship Development Board (NEDB), Why do Entrepreneurs fail - The FOUR Entrepreneurial Pitfalls (Peter Drucker), Women Entrepreneurs: Reasons for Low / No Women Entrepreneurs, Role, Problems and Prospects. Case studies of Successful Entrepreneurial Ventures, Failed Entrepreneurial Ventures and Turnaround Ventures.

Unit IV: Management Theories and **Managerial Work (7h)**
Stages of team development (Tuckman), Team role theory (Belbin), Management roles (Henry Mintzberg), Situational leadership (Blanchard), Hierarchy of needs (Maslow), Five competitive forces (Porter), Interview of mid / large cap industry professional (preferably MBA) to understand practical usage of any of these theories. Business communication**,** communication process, communication styles, and communication forms in organizations, fundamentals of business writing, patterns of business messages, report writing, public speaking and oral reporting, verbal and nonverbal communication, use of visual and presentation aides, and cultural and international dimensions of communication, Organization behavior.

Unit V: Project Management based on Microsoft Project (7h)

Introduction, Project management concepts, Using Microsoft project, Start your plan, Adding resources to the model, Resource management & crashing, Resource rates & using calendars, Handling multiple projects, Uncertain activity times, Tracking, Baseline & reports, Assignment – case study of a project involving various resources, timeline & costs, Business excellence through six sigma and kaizen.

Unit VI: Marketing Management (7h)

Introduction to the basic concepts and principles of marketing, Consumer Behavior, Marketing Research, Product & Brand Management, Integrated Marketing Communications, Marketing Channels, International Marketing, Internet Marketing, Business-to-Business Marketing, Understanding the role of marketing in society and the firm, marketing concept, market segmentation, target marketing, demand estimation, product management, channels of distribution, promotion, and pricing. Introduction to the concepts, principles, and techniques used in gathering, analyzing, and interpreting data for marketing decisions.The role of information in marketing decisions, research problem, formulation, research design methods, measurement and design of research instruments, sampling design, data collection methods, data analysis, and presentation of research results.

Reference Books:

1. Entrepreneurship: New Venture Creation - David H. Holt, Prentice Hall PTR, 1992.
2. Entrepreneurship - Robert D. Hisrich, Michael P. Peters, Dean A. Shepherd, McGraw-Hill Education, 2013.
3. The Culture of Entrepreneurship - Brigitte Berger, Ics Press, 1991.
4. Project Management - K. Nagarajan, New Age International, 2004.
5. Dynamics of Entrepreneurship Development - Vasant Desai, Himalaya Publishing House, 2001.
6. Entrepreneurship Development: An Interdisciplinary Approach, S. G. Bhanushali, Himalaya Publishing House, 1987
7. Thought Leaders – Shrinivas Pandit, Tata McGraw-Hill Education, 2002.
8. Entrepreneuring: The Ten Commandments for Building a Growth Company, Steven C. Brandt, Archipelago Pub., 1997.
9. Business Gurus Speak - S.N.Chary, 2002.
10. The Entrepreneurial Connection – Gurmit Narula, Tata Mc-Graw Hill.
11. Business Marketing Management: B2B, Michael Hutt, Thomas Speh, Cengage Learning, 2012.

Elective II

409365 (3) : Advanced Polymer Synthesis

Teaching Scheme:	**Examination Scheme:**
Lectures: 3 h/week	In Semester: 30
	End Semester: 70
	Total: 100

Objectives:

To impart the awareness of recent advances in polymer material synthesis, current research interest and novel concepts at National and International level.

Unit I: Polymerization **(7h)**
Probability and statistics-statistics of polycondensation, chain polymerization, branching and gelation. Copolymer sequence distribution. Chain microstructure and its characterization by spectroscopy, order and morphology of polymers.

Unit II: Advanced polymer synthesis and mechanisms **(7h)**
Ring opening metathesis polymerization (ROMP), ring forming polymers, living cationic and radical polymerization, metal catalyzed olefin polymerization, cyclopolymerisation, oxidative polymerization, dispersion polymerization, mini-dispersion polymerization, microbial synthesis of polymers, template polymerization.

Unit III: Specialty-application polymers **(7h)**
Synthesis of silicones, polyphosphazenes, polythiazyl, polybenzimidazole, polybenzoxazole, polybenzthiazole, Rubbers: silicones, epichlorohydrin, fluroelastomers, polysulphides, polyurethane, acrylic rubbers, silane-containing polymers.

Unit IV: Branched and dendritic polymer synthesis **(7h)**
Surface functionalization of polymers, graft copolymerization, approaches to making comb and graft architectures, grafting onto existing polymer surfaces, surface engineering using graft copolymers, oxidative coupling branched and dendritic polymers and its synthesis, new developments in telechelic polymers, biodegradable polymers.

Unit V: Supramolecular chemistry **(7h)**
Introduction, concept - from primary structure to complex structure, types of self assembly and non-covalent interactions, macromolecular systems via secondary bonding, use of various forces to build structures, self assembled polymers, supramoleculer and metallo supramoleculer polymers and their applications.

Unit VI: Frontiers in Polymer Synthesis **(7h)**
Development of nano structured materials for advanced properties and functions in microelectronics and biotechnology, new synthetic techniques including metal-based catalysts for polymer synthesis, the utilization of renewable resources in macromolecule formation, synthesis and applications of high-surface area polymer networks, development of photoregulated polymerizations, synthesis and properties of cyclic polymers.

Reference Books:

1. Comprehensive supramoleculer Chemistry, Pergamon, Vol 1-10, 1999
2. Core concepts in supramoleculer chemistry and nano-chemistry, J W Steed, 1st Edition, Wiley
3. Polymer Handbook, 2 Volumes Set, J. Brandrup, E. H. Immergut and E. A. Grulke
4. "Block Copolymers by Transformation of 'Living' Carbocationic into 'Living' Radical Polymerization." Coca, Simion, and Krzystof Matyjaszewski. Macromolecules 30 (1997): 2808-2810.
5. Essentials of polymer science and engineering, P C Painter, M M Coleman, DE Stech publications, Inc., USA.
6. New Frontiers in Polymer Synthesis edited by Shiro Kobayashi, Springer.
7. Polymer Science, New age international (P) Ltd. Publishers, V.R. Gowarikar, Pearson publication, 2003.
8. Self-Assembly and Nanotechnology Systems: Design, Characterization, and Applications, Yoon S Lee, John Wiley & Sons, Inc., 2012
9. Supramolecular Chemistry, Jonathan W. Steed, Jerry L. Atwood, John Wiley & Sons, 2009
10. Specialty Polymers: Materials and Applications, Faiz Mohammad, I. K. International Pvt Ltd, 2007.
11. Polymer Characterization: Laboratory Techniques and Analysis, Nicholas P. Cheremisinoff, Univ. Press of Mississippi, 1996.

409366: Project Phase I

Teaching Scheme:	**Examination Scheme:**
Practical: 2 h/week	TW: 50
	Total: 50

The department should display the list of approved teachers (guides) along with the project titles proposed by them. The students should be given liberty to choose the project area and project guide of their own choice. The student can also choose a state-of-the-art problem of their own interest based on the recent trends in Polymer Engineering / Science in consultation with the guide. They shall work on the designated problem either individually or in groups (maximum **two** students per group).

During the first term the students are required to:

1. Define the research problem.
2. Write a *research proposal*, which should contain –
   a. Project title
   b. Introduction
   c. Origin of the problem
   d. Literature review of research and development at national & international level
   e. Significance of the problem
   f. Objective
   g. Methodology
   h. Details of collaboration (if any)
3. Carry out *preliminary* experimental investigations or product design or process design etc.
4. Summarize the results (if any).

The student is required to prepare a month wise **work plan** (for both semesters) immediately after the allotment of the project and the department is required to maintain a progress report of every student/project. The progress report should reflect monthly progress done by the student as per the work plan. The progress report is to be duly signed by the respective project guide by giving the remarks/marks/grades etc. on the periodic progress done by the student at the mid of the term and should be **submitted along with project report** at the end of respective terms to the examiners as a supporting document for evaluation. Every student will be examined orally based on the topic of his/her project and relevant area to evaluate his understanding of the problem and the progress made by the student during the term.

Students should submit a neatly typed and spiral bound *research proposal* at the end of the term in the following format.

Font: Times New Roman, Font size: 12, Headings: 14, Spacing: 1.5, typed on one side of the A4 size paper with proportionate diagrams, figures, graphs, photographs, tables etc.

Referencing style:

1. Guo J. X. and Gray D. G., Chiroptical behavior of (acetyl)(ethyl)cellulose liquid-crystalline solutions in chloroform, *Macromolecules, 22,* (1989), 2086.
   (Reference numbers should be mentioned in the main text as a superscript)

The proposal should contain:
Page 1: The cover page - should mention: Project title, Name of the student, Name of the guide, Exam seat number and Year.
Page 2: Certificate
Page 3: Index
Page 4 onwards: Research proposal (as above), experimental investigation details and result if any.
Last page: References

The department should prepare a template of the format of the project report and supply it to the students so as to maintain the uniformity in the project reports.

Students are encouraged to participate and present their project work in various events, competitions, conferences and seminars etc.in consultation with their guide.

Note: The project guides are required to educate the students about antiplagiarism policy of SPPU and apply the same while doing the project.

409367: Industrial Training Evaluation

Teaching Scheme:
3-4 week industrial training

Examination Scheme:
TW: 50 marks

Students are required to undertake Industrial Training in an industry of repute and related to the field of polymer engineering/science for a period not less than 3 weeks and not more than 4 weeks immediately after third year second semester examination is over.

The College/Department is required to allot a **Mentor** to every student who will monitor the activity of a student during Industrial Training. The Mentor/Teacher shall guide and supervise the activities of the student while the student is undergoing Industrial Training. The Industrial Training report is to be prepared in consultation with the Mentor/Teacher and industry.

Students are required to submit neatly typed and spiral bound training report after joining the college. The department should arrange a **presentation session** (for 10 mins. using maximum 5-7 slides) for all the students to share their experience during the Industrial training at the start of the term. The report should include information about working of the industry and also specific information of the work done by the student in the industry. The students are also required to attach an Original Certificate issued by the competent authority from the industry where he / she has undergone training mentioning the successful completion of the training. The report must be duly signed by his/her Mentor.

The student is required to present the report of the skills / knowledge acquired by her/him during the training for his **industrial training evaluation/TW**. Industrial Training Evaluation/TW Assessment shall be done jointly by the mentor and external examiner based on the knowledge/skills gained by the student during the Industrial Training and the report.

409368: Introduction to Polymer Industries I

Teaching Scheme:	**Examination Scheme:**
Interaction with industry	TW: 25 marks

It is **mandatory** that the students along with the mentor/teacher to visit a large scale Polymer Industry based on various subjects he/she is studied/studying at TE/BE. These may include manufacturing, synthesis, processing, compounding, design, tooling, equipment manufacturing industry and reputed research/testing laboratories etc. to impart thorough industrial exposure and interaction with the industry. Minimum **three types** of industries and/or laboratories must be covered during a visit or two during the semester.

Students are required to submit neatly typed and spiral bound combined industrial visit report at the end of the term for the purpose of term work assessment. The report should include information about the various aspects and working details of the industry. The student is required to summarize knowledge acquired by her/him during the interaction with various industries.

The students are required to attach a copy (attested by mentor/teacher) of *Original Attendance Certificate*, to the report mentioning the date of visit, issued by the competent authority from the industry where he / she has visited.

The students will be evaluated based on the report submitted, knowledge acquired during the industrial visit at the end of the semester under the head TW for 25 marks.

(Note: As the industrial visit is mandatory the term is not to be granted if any student fails to attend industrial visit.)

Term II

409369: Advanced Polymer Rheology

Teaching Scheme:
Lectures: 4 h / week
Practical: 2 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
OR: 50
Total: 150

Unit I (8 h)

Stress tensor, principal stress and invariants, polar decomposition theorem, finger tensor, strain tensor, inverse deformation tensors, principal strains, uniaxial extension and simple shear in neo-hookean solid, rate of deformation tensor, Newton's law in three dimensions, uniaxial extension, viscosity models for general viscous fluids and visco-plastic models.

Unit II (8 h)

General linear viscoelastic model, stress relaxation and creep, non-linear viscoelasticity - normal stress difference in shear, shear thinning, interrelations between shear functions, extensional thickening, differential-type constitutive equations - single mode differential constitutive equations and multimode constitutive equations for viscoelastic fluids, integral type constitutive equations, rate-type constitutive equations for viscoelastic fluids, material functions for steady state shear flow, oscillatory shear flow, material functions for steady state extensional flow.

Unit III (8 h)

Shear rheometer: sliding plates, falling ball rheometer, concentric cylinder rheometer, cone and plate rheometer, parallel disks, capillary rheometer, slit rheometer and squeezing flow behavior.

Unit IV (8 h)

Extensional rheometry: simple extension - end clamps, rotating clamps, buoyancy bath, spinning drop, lubricated compression, planner squzeeing, sheet stretching, multiaxial extension, fiber spinning, tubeless siphon, bubble collapse, stagnation flow.

Unit V (8 h)

Rheology of polymeric liquids: polymer chain conformation, zero shear viscosity, rheology of dilute polymer solutions, entanglement, Reptation Model, effect of long chain branching, effect of molecular weight distribution, temperature dependence.

Unit VI (8 h)

Rheology in polymer processing operations: Calendaring and two roll mill, Twin screw extruders, Blow molding, Wire coating, Thermoforming, Sheet extrusion, Internal mixers, Rubber extrusion

List of Experiments (min 8):

Minimum eight experiments based on methods for measurement of the rheological properties of following –

1. Rheological characterization of polymeric fluids.
2. Shear flow measurement
3. Elongation flow - filaments and sheets
4. Drag induced shear flow.
5. Rotational viscometer.
6. Extrusion rheometers.
7. Slippage on solid wall.
8. Uniaxial, biaxial and planar extension.
9. Small strain experiments.
10. Mooney's viscometer.
11. To study the variation in viscosity with respect to temperature using capillary rheometer.
12. Fitting of rheological models using capillary rheometer [power low model, Ellis model etc.].
13. Estimation of Bagley's correction factor using capillary rheometer.

Reference books:

1. Rheology, Principles, Measurements and Applications, Christopher W. Macasko, Wiley-VCH,1994
2. Rheology and Processing of Polymeric Materials, Vol. 1, Oxford University Press, 2007
3. Rheology: Concepts, Methods, and Applications, Prof. Dr. Alexander Ya. Malkin, Prof. Dr. Avraam I Isayev, ChemTec Publishing, 2006
4. Dynamics of Polymeric Liquid, Volume I, R. Byron Bird, Robert C Armstrong, Ole Hassager, John Wiley and Sons, 1976
5. Polymer Processing Fundamentals, Tim A Osswald, Hanser Publishers, Munich, 1998.
6. Melt Rheology and its Role in Plastic Processing: Theory and applications, John M. Dealy, Kurt F. Wissbrun, Reprinted by Chapman and Hall,1999.
7. Principles of Polymer Engineering Rheology**,** James Lindsay White**,** John Wiley & Sons, 20-Jul-1990.

409370: Product Design and Polymer Testing

Teaching Scheme:	**Examination Scheme:**
Lectures: 4 h / week	In Semester: 30
Practical: 2 h / week	End Semester: 70
	TW: 25
	OR : 50
	Total: 175

Objective:
The objective of the subject is to impart the knowledge of product design and testing to the students based on their understanding of polymer rheology. The subject prepares the students for mould and die design which are studied from the product design point of view and standard testing methods.

Unit I: Product Design Overview **(8 h)**
Materials of construction, Procedure and steps in product design, concurrent or parallel engineering approach to product design, pseudo-elastic design method, application of creep curves, stress relaxation, isometric curves in plastic product design, Plastic Behaviors, Fabricating Processes, design considerations for injection molded components - design considerations for bearing in plastics, life cycle assessment.
Design Optimization**,** Design Foundation, Design Approach, Design Analysis Approach, Static Stress, Dynamic Stress, Basic Design Theory, Conceptual Design Approach, Design Analysis.

Unit II: Design Parameters and Computer Aided Design **(8 h)**
Design Parameters, Load Determination, Design Analysis Process, Stress-strain Behavior, Combined Stresses, Product Design**,** Geometric Shape, Plate, Beam, Rib, Column, Torsion, Sandwich, Gear, Bearing, Grommet, Gasket, Shape, Pipe, Spring, Hinge, Press Fit, Snap Fit, Tape, wall thickness, corners and bosses, joints, design of joints for bonding adhesives, Computer Aided Design, Design accuracy and efficiency, SoftwarePrograms, DesigningGraphics, Structural Analysis, Software Analysis, Synthesizing design, CAD Prototyping, Rapid Prototyping, Plastic Performance, Selecting plastic, Design reliability**,** Testing, Quality Control, Product failure, Safety Factor.

Unit III: Mechanical and Thermal Properties **(8 h)**
Indian and international standards for testing and test methods, mechanical properties **-** short term and long term mechanical properties and its significance and importance, determination of tensile and compressive properties, determination of flexural properties, impact properties, shear properties, determination of hardness, abrasion resistance and fatigue resistance, methods for determination of creep and fatigue properties, thermal properties **–** tests for elevated performance -heat deflection temperature (HDT), Vicat softening point, determination of thermal conductivity and coefficient of thermal expansion.

Unit IV: Other Test Methods **(8 h)**
Permeability properties: sorption, diffusion and permeation, analytical tests: determination of specific gravity, density by density gradient method, bulk density, moisture absorption, particle size analysis, non-destructive testing: ultrasonic testing, beta transmission, X-ray fluorescence, testing of foam plastics, testing methods for packaging products, pipes, films, storage tanks etc. study of acoustic properties

Unit V: Optical and Electrical Properties **(8 h)**
Optical properties: refractive index, luminous transmittance and haze, photoelectric properties, color, specular gloss, interaction of light with polymers reflection and refraction of light by polymers, birefringence, birefringence in isotropic and anisotropic materials, orientation birefringence and its

measurements in polymers. Electrical properties: dielectric strength, dielectric constant and dissipation factor, volume resistivity and surface resistivity, arc resistance, EMI shielding, electrical conductivity measurements in polymers, static charge in polymers, dynamic electric analysis(DEA).

Unit VI: Chemical, weathering and flammability testing (8 h)

Chemical properties: solvent stress cracking resistance, stain resistance of plastics, environmental stress cracking, immersion tests, barrier properties. Weathering Properties: outdoor weathering tests accelerated weathering tests, resistance of plastics to fungi, bacterial growth. Flammability: limiting oxygen index test, UL 94 flammability tests, flammability tests for rigid and non-rigid plastics, flammability tests for cellular plastics, ignition properties of plastics.

List of Experiments (total 8):

1. Minimum **three experiments** based on product design must be conducted as compulsory experiments.
   Any five experiments form the list below.
2. To determine the tensile strength and percentage elongation of film in machine/longitudinal and transverse direction.
3. To determine the tensile strength at break & yield & % elongation of dumbbell shaped specimens of various polymers.
4. To determine the Izod impact strength of various polymers.
5. To determine the falling dart impact strength for films.
6. To determine the heat deflection temperature.
7. To determine the Vicat softening temperature.
8. To determine the coefficient of friction of films.
9. To determine the specific gravity of rubber sample and other polymeric samples.
10. Study of volume & surface resistivity and to determine the same experimentally.
11. To find out environmental stress crack resistance of polyethylene and other polymeric samples.
12. To carry out water absorption test for various polymers.
13. Determination of burst strength of pipes and determination of pressure rating of pipes.

Reference Books:

1. Plastics Part design for injection moulding, Dr. Robert A Malloy, Hanser Publications, Munich, 1994
2. Handbook of plastics Testing Technology, 2nd edition, Vishu Shah, John Wiley and Sons Inc, New York, 2008
3. Handbook of plastics testing and failure analysis, 3nd edition, Vishu Shah, John Wiley and Sons Inc, New York, 2007
4. Plastics Engineered Product Design, 1st Edition, Rosato & Rosato, Elsevier Science, 2003.
5. Understanding Plastics testing, Donald C Hilton, Hanser Gardener Publications Inc, 2004
6. Plastics testing and characterization: Industrial applications, ,Alberto Naranjo, Maria Noriega, Tim Osswald, Alejandro Roldan-Alzate, Juan Diego Sierra, Hanser Gardener Publications Inc,2008
7. Handbook of Polymer Testing: Physical Methods, Roger Brown, CRC press, 1999

Elective III

409371 (1) : Polymer Physics and Characterization

Teaching Scheme:
Lectures: 3 h/week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Unit I: FTIR **(7h)**

Fourier Transform Infrared Spectroscopy (FTIR): Molecular vibrations, basic theory of Fourier transform spectroscopy, inter-ferogram, data points collection, instrumentation and advantages of FTIR spectrophotometer, structural and conformational changes in polymers stress induced changes in polymer, chemical transformation and degradation in polymers, surface studies by attenuated total reflectance (ATR).

Unit II: NMR **(7h)**

Nuclear Magnetic Resonance Spectroscopy **(**NMR**)**: Theory of NMR phenomenon, relaxation process, chemical shifts, spin-spin interaction, interpretation of NMR spectra, instrumentation-continuous and pulsed NMR, characterization of polymers and qualitative and quantitative analysis of elements using NMR spectroscopy.

Unit III: Separation Techniques and X-ray Diffraction **(7h)**

Separation techniques – Gel permeation chromatography (GPC), high-performance liquid chromatography (HPLC), mol. wt and mol. wt distribution measurements. X-ray diffraction: Properties of x-rays, diffraction of x-rays, Bragg law of X-ray diffraction, lattice and powder diffraction methods, crystal geometry, structural determination of polymers using wide and small angle X-ray diffraction techniques.

Unit IV: Microscopy and Surface properties **(7h)**

Microscopy: Basic principle of electron microscopy; specimen preparation, replication, coating and surface pretreatment, structure determination of semi-crystalline polymers by scanning electron microscope (SEM), transmission electron microscopy (TEM) and atomic force microscopy (AFM), Lameller, fibrillar globular and spherulite structures in polymers. Surface properties: Surface energy, contact angle measurements of polymers and evaluation of compatibility of polymer in polymer blends by surface properties.

Unit V: Thermal Analysis **(7h)**

Thermal Analysis: Thermal transitions and their classification in polymers, glass transition temperature and its mechanism, melting point of semi crystalline polymers, characterizing polymer and polymer blends using differential thermal analysis (DTA), derivative thermogravimetry (DTG) and differential scanning calorimeter (DSC) techniques, thermal conductivity in polymers,use of DSC for determination of kinetics of crystallization, thermogravimetric analysis (TGA), thermomechanical analysis (TMA), dynamic mechanical analysis (DMA), dynamic mechanical thermal analysis (DMTA).

Unit VI: Optical and Electrical Properties **(7h)**

Optical Properties: Interaction of light with polymers, reflection and refraction of light by polymers, birefringence, birefringence in isotropic and anisotropic materials, orientation birefringence and its measurements in polymers.Electrical Properties:Electrical conduction in polymers, dielectric properties, electrical conductivity measurements in polymers, static charge in polymers, dynamic electric analysis (DEA), commercial application of conducting polymers.

Reference books:

1. Polymer Characterization: Physical Techniques, D. Campbell and J. R. White; Chapman & Hall, London (1989).
2. Introduction to Physical Polymer Sciences, L.H. Sperling, J. Wiley N.Y, 1993.
3. Instrumental methods of analysis – Willard, Dean and Merritt, Wadsworth Pub Co., 1988
4. Analysis of Polymers, T.R. Crompton Pergmon Press, N.Y., 1989.
5. Textbook of Polymer Science- Fred W. Billmeyer, Wiley-Interscience, 1984.
6. Molecular Motions in High Polymers, R. T. Crompton, Pergmon Press, N.Y., 1989.
7. The Identification of Plastic and Rubber- K. J. Saunders, Chapman and Hall, London, 1966.
8. Mechanical Properties of High Polymers, I. M. Ward, John Wiley, 1979.

Elective III

409371 (2) : Polymer Thermodynamics and Blends

Teaching Scheme:
Lectures: 3 h/week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Unit I: Introduction to thermodynamics (7 h)
Introduction, fundamentals, laws of thermodynamics, thermodynamic functions and relations, lattice theories, entropy of mixing, heat of mixing, mixtures, composition variables.

Unit II: Phase Equilibria and Stability (7 h)
Phase equilibria – phases, Gibb's phase rule, free energy of mixing, phase stability, phase diagrams, multicomponent mixtures, crystallizable components, ideal polymeric mixtures, regular mixture, effect of molecular weight distributions on phase equilibria, spinodal and critical Point.

Unit III: Mixing theories and models (7 h)
Derivation of the Flory-Huggins entropy of mixing, alternative derivations, Huggins correction, polymer thermodynamic models - Flory-Huggins models, equation-of-state models (concepts, Helmholtz free energy, corresponding states, cell partition function, chain flexibility), specific interaction - hydrogen bonding interaction, dipole-dipole interaction, ion–dipole & ion-ion interaction and additional specific interaction.

Unit IV: Introduction to blends (7 h)
Definition of polymer blends, compatibility, miscibility etc., classification of polymer blends, advantages of blends over conventional polymers, significance of polymer blend technology, different steps involved in designing of a blend, different methods of blending.

Unit V: Compatibilization and Phase Morphology (7 h)
Role of compatibilizers in blend technology, techniques of compatibilization, phase structure development in polymer blends, study of factors affecting the morphology of polymer blends, structure determination of polymer blends, Characterization of Polymer Blends, Studies of physical properties of polymer blends, toughness of polymer blends.

Unit VI: Rheology and IPN (7h)
Rheological properties of polymer blends, rheological criteria, interfacial criteria, synergy & additivity, log additivity & inverse additivity rules, effect of interaction parameters on properties, different polymer blends and their applications with case studies,interpenetrating polymer network technology and its applications, permeability of blends to gases and vapors.

Reference books:

1. Concepts of Polymer Thermodynamics -Vol. 2; Menno A. Van Dijk & André Wakker, TECHNOMIC® publication, 1997.
2. Polymer Physics; Michael Rubinstein, Ralph H. Colby; OxfordUniversity Press, 2003.
3. Handbook of Polymer Solution Thermodynamics; Ronald P. Danner, Martin S. High; American Institute of Chemical Engineers, New York, 1993.

4. Introduction to chemical engineering thermodynamics; J. M. Smith, Hendrick Van Ness.
5. Polymer Blends A Comprehensive Review; Lloyd M. Robeson; Hanser Publication, 2007.
6. Polymer Blends; D.R.Paul & Seymour Newman, Vo. 1 & 2, Academic Press, New York, 1978.
7. Advance in Polymer Blends & Alloys Technology by Malvyn Kohudic, Technomic® publication, 1988.
8. Plastics Materials J. A. Brydson, Butterworth Scientific, 1990.
9. Polymer Blends & Alloys; Folkes & Hopes Blackie, Academic Professional 1993.
10. Polymer Alloys and Blends - Thermodynamics & Rheology; L.A. Utracki Hanser Publishers, New York, 1996.
11. Commercial Polymer Blends; L.A. Utracki, Chapman & Hall, London, 1998.
12. Introduction to Physical Polymer Science, L.H. Sperling, Wiley-Interscience, 2001.
13. Polymer Blends and Alloys -An Overview; R P Singh, C K Das, S K Mustafi; Asian Books Pvt. Ltd, 2002.
14. Polymer Blends-Encyclopedia of Polymer Science and Technology, John Wiley & Sons, 2005.

Elective III

409371 (3) : Elastomer & Rubber Technology

Teaching Scheme:
Lectures: 3 h/week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Objective
In this course the details pertaining to raw materials, formulations, processing, testing, applications have been presented. A sound understanding of these polymeric materials would equip the students for careers in rubber industry.

Unit I: Introduction to Rubber Elasticity (7h)
Revision of basic concepts and stages in rubber technology, rubber elasticity, physics of raw and vulcanized rubber, kinetic & thermodynamics theory of rubber elasticity, stress-strain relationships for vulcanized rubber, molecular basis for material to act as a rubber, classification and chemical constitution of different types of rubbers, glass - rubber transition, storage hardening and crystallization of natural rubber, crystallization in the stretched state, stress-strain relationship for vulcanized rubber, rebound resilience.

Unit II: Compounding and Ingredients (7h)
Review of elastomeric materials - selection criteria for elastomers for intended applications, mastication and compounding behavior, basics of adhesion of rubber to metal, principles of compounding, design of rubber compounds for various applications, machinery and method used for compounding, chemicals and additives used in rubber compounding, need for addition, function, level and stage of addition of various additives such as peptizers, mechanism of mastication and role of peptizers, examples; antioxidants : classification and examples, antiozonants; accelerators : classification according to cure rate, criteria for selection, mode of functioning, examples for various rubbers; activators, fillers: particulate, non-reinforcing, examples and effect on properties; C black : types, features important in reinforcing action, mechanism of reinforcement, methods of incorporation; reinforcements, chords and fabrics; blowing agents; colorants; processing aids: tackifiers, plasticizers, softeners, extender oils.

Unit III: Vulcanization and Rheometers (7h)
Vulcanization of rubbers: vulcanization by sulphur, peroxides and by other methods, kinetics of vulcanization, chemical reactions, factors affecting rate of vulcanization, OtherRubbers:Tetrafluoroethylene-propyleneRubbers,Polyphosphazene elastomers, Polynorboromene, Polypentenamer, Carboxylated Rubbers, Polyalkalynes, Polytetrahydroduran, Nitroso & Traizine Elastomers, Recent Developments, rheometers for rubber- oscillating disk rheometer, moving die rheometer, Mooney viscometer, Plastometer, Curometer etc.

Unit IV: Machinery (7h)
Details of machines, methods and processing parameters for various types of: Mixing Mills, Calenders, Extruders, Presses, Molding Machines, Hand Building & Forming Equipments, Vulcanization Equipments, Finishing of Rubber Components, Latex Processing & Testing Equipments, mould and die design consideration for rubber products.

Unit V: Manufacturing of Rubber from Monomers and Other Products (7h)

Butadiene (1,3-butadiene), production of Butadiene from: n-Butenes, n-Butane, by steam Cracking of Naphtha Petroleum Fraction, Ethyl Alcohol, Reppe Process, acetaldehyde, Isoprene(2- methyl-1-,3-Butadiene), production of Isoprene by: the Propylene Dimer Process, Dehydrogenation of Isopentane and /or 2- Methyl Butenes, Isobutene Formaldehyde process, acetone-acetylene Process, Chloroprene(2-Chloro-1,3-Butadiene), production of Chloroprene from: Acetylene, Butadiene, Ethylene, Propylene, Isobutene(Isobutylene). Technology of manufacture of products such as tyres, tubes, conveyor belts and flat belts, cellular products, hose technology, cables, footwear and latex goods, latex products such as dipped goods, foams, rubbers used in power transmission, O-rings, gaskets and seals. Reclaim rubber, types, manufacturing processes, applications.

Unit VI: Testing (7h)

Determination of cure rate of rubbers, testing and analysis of raw rubber, compounds and vulcanizates, testing of finished rubber products, test methods & fundamentals, determination of low temperature properties, permeability and cure adhesion, test methods for determination of free sulfur, ash content, moisture content and total solid content, test methods for hardness, abrasion and wear resistance, tear resistance, weathering resistance, heat resistance, flex fatigue resistance, compression set, resilience, accelerated ageing, ozone resistance.

Reference books:

1. Rubber Technology Edited by Maurice Morton Kluwer, Academic Publishers, 2010
2. Rubber Compounding Chemistry and Application by Bredan Rodgers Publisher: CRC Press; 1 edition, 2004
3. Rubber Compounding by Fred W Barlow, Mercel Dekker Inc, 1993
4. The Physics of Rubber Elasticity by L. R. G. Treloar, Publishers: Oxford University Press Inc, 2005
5. Natural Rubber Science and Technology by A. D. Roberts, Oxford Science Publication, 1988
6. Engineering with Rubber: How to design Rubber components by Alan N Gent Publishers: HANSER PUBLISHERS, 2001
7. Practical Rubber Compounding and Processing by B. W. Evans Publishers: Applied Science Publication, 1981
8. Rubber Technology and Manufacture by C M Blow, Butterworth-Heinmann, 2nd Edition, 1982
9. Development of Rubber Technology by A Whelan, K S Lee, and T Whelan Publishers: SPRINGER, 1st Edition, 1979
10. Rubber to Metal Bonding by B. G. Crowther, RAPRA TECHNOLOGIES, 1996
11. Advances in the bonding of rubber to various substrates by RAPRA TECHNOLOGIES (2001)
12. Rubber Handbook by Babbit (Author), R T Vanderbilt Publishers, 13th edition,1990
13. Handbook of Elastomers, Second edition Edited by Anil K Bhowmick and Howard L Stephens, Mercel Dekker, Inc, (2001)
14. Rubber Products Manufacturing Technology by Anil K Bhowmick, Publishers: CRC Press, 1st edition,1994
15. Rubber Technology Handbook, by Werner Hoffmann, HANSER Publishers, 1989
16. Shaft Seals Dynamic Application by Les Horve, Mercel Dekker, 1995

Elective IV

409372 (1) : Polymer Nanotechnology

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Unit I: Introduction (7h)
Introduction to nanotechnology and nanomaterials, how it all began: synthesis of carbon buckyballs, list of stable carbon allotropes extended, fullerenes, metallofullerenes, solid C60, bucky onions, nanotubes, nanocones, properties of individual nanoparticles, methods of synthesis for carbon nanostructures, carbon nanofilaments.

Unit II: Synthesis Procedures of Nanomaterials (7h)
Bottom-up vs. top-down, epitaxial growth, self-assembly, modeling and applications production techniques of nano-tubes carbon arc bulk synthesis in presence and absence of catalysts high-purity material (bucky paper) production using pulsed laser vaporization (PLV) of pure and doped graphite high-pressure CO conversion (HIPCO) nano-tube synthesis based on boudoir reaction chemical vapor deposition (CVD)

Unit III: Characterizations of Nanomaterials (7h)
Optical microscopy, electron microscopy, secondary electron scattering, back scattering, scanning probe microscopes, focused ion beam technique, X-ray diffraction, SPM-AFM, STM, optical, electronic and vibrational spectroscopic tools etc..

Unit IV: Polymer Nanocomposites and Processing (7h)
Polymer nano-composites: definitions, incorporation of nanomaterials in polymer matrix: interface, why nanomaterials, methods of preparation of polymer nanocomposites, nanoparticle dispersion and reinforcement by surface modification, surface modification of carbon nanofibers, compounding of layered silicate nanocomposites, nanoparticlaes in rubber processing, nanopolymers by microemulsion, Nanotechnology and tissue engineering.

Unit V: Nanomaterials for Polymer Nanocomposites (7h)
Classification of nanoparticles, layered nanoparticles (Clay), fibrillar nanoparticles (carbon nanotubes (CNTs) etc.) and other nanoparticles, polymer clay nano-composites (PCNC), preparation steps - intercalation, exfoliation & functional CPNC**,** PNC with CNTs for electrical conductivity, PNC with CNTs - thermoset matrix and CNTs - thermoplastic matrix, comparison of PNC with normal composites based on composition, mechanical, thermal, rheology, morphology & process parameters.

Unit V: Properties of Nanomaterials (7h)

Rheology of polymeric nanocomposites, VGCF and its alignment, nanocomposites of liquid crystalline polymers. Characterization of polymer nanocomposites: TEM and related techniques, mechanical properties of nanocomposites, mass transport through polymer nanocomposites, flammability properties, electrical properties, Thermal conductivity, Electrospun nanofibers.

Reference Books:

1. Nanotechnology and Tissue Engineering: The Scaffold**,** Ed. Cato T. Laurencin, Lakshmi S. Nair, CRC Press, 2008.
2. Synthesis and Characterization of Nanopolymers by Microemulsion, Uttam Kumar Mandal, Pallavi Bhardwaj, Saroj Aggarwal, LAP Lambert Academic Publishing, 2012.
3. Rubber-Clay Nanocomposites: Science, Technology, and Applications Ed. Maurizio Galimberti, John Wiley & Sons, 2011.
4. Introduction to Nano Science, (CRC Press of Taylor and Francis Group LLC), G. Louis Hornyak, Joydeep Dutta, Harry F. Tibbals and Anil K. Rao, May 2008, 856pp, ISBN-13: 978142004805
5. Ashby, Michael F., Ferreira, *Paulo* J., Schodek, Daniel L. 2009. *Nanomaterials and nanotechnologies*: An overview. In: Nanomaterials, Nanotechnologies and Design, Linacre Haus, Jordan Hill, Oxford, 2009.
6. Introduction to Nanoscience and Nanotechnology, K. K. Chattopadhyay, A.N. Banerjee, PHI Learning Private Limited.
7. Applied Colloid and Surface Chemistry, Richard M. Pashley and Marilyn E. Karaman, John Wiley & Sons Ltd, 2004.
8. Nanostructuring Operations in Nanoscale Science and Engineering, Kal Renganathan Sharma, The McGraw-Hill Companies, Inc. ISBN: 978-0-07-162609-5, 2010.

Elective IV

409372 (2) : Polymers in Advanced Applications

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Unit I: Polymers in defense and Aerospace applications (7 h)

Composites including thermosets, thermoplastics and nanocomposites; fiber reinforcement of composites and specialized applications, shape memory polymers and their composites, novel materials and processes, carbon nano fibre -based materials, inorganic nano-materials and coatings, coatings for solar radiation abatement, self healing of fibre reinforced polymer composites, and use of shape memory alloys integrated into composites for improved damage tolerance and lightening strike protection, phosphazene elastomers.

Unit II: Polymer nanocomposites applications (7 h)

Homogeneous and heterogeneous catalysis, sensorics, filter applications, and optoelectronics, tissue engineering, orthopedic applications, drug delivery from nanotubes, protein immobilization etc., food packaging, nanotechnology in health care**,** drug, sensors, electronics, nanodevices etc..

Unit III: Polymers in pharma and biomedical applications (7 h)

Use of following polymeric material from packaging to fabrication of the most sophisticated devices and drug delivery and other applications. Water-Soluble Synthetic Polymers**:** Poly (acrylic acid), Poly (ethylene oxide), Poly (ethylene glycol), Poly (vinyl pyrrolidone), Poly (vinyl alcohol), Poly (isopropyl acrylamide) and poly (cyclopropyl methacrylamide), thermogelling acrylamide derivatives. Cellulose-Based Polymers: Ethyl cellulose, Carboxymethyl cellulose, Hydroxyethyl and hydroxypropyl celluloses, Hydroxypropyl methyl cellulose, Cellulose acetate phthalate, Alginic acid, Carrageenan, Chitosan. Water-Insoluble Biodegradable Polymers. Starch-Based Polymers. Polyurethane, Silicones, medical grade adhesive, Biodegradable tissue adhesives in surgery, Polycarbonate, Polychloroprene, Polyisobutylene , Polycyanoacrylate a drug carrier in nano and microparticles
Poly (vinyl acetate), Polystyrene, Polypropylene, Poly (vinyl chloride), Polyethylene
Poly (methyl methacrylate), Poly (hydroxyethyl methacrylate), tissue engineering.

Unit IV: Advanced polymer materials and applications (7 h)

Liquid crystalline polymers, electro-active polymers, polymers for photoresists, fluorinated polymers, chiral polymers, polymers in lithography, fluoropolymers, polymer electrolytes and gel electrolytes, hydrophilic polymers, ionic polymers, hydrogels and stimuli sensitive hydrogels, functional polymers: photoconductive polymers, elecroconductive polymers, piezoelectric polymers, light sensitive polymers, ion exchange resins, polymeric reagents, polymers as catalysts, polymers as substrates, polymer thin films, photoresponsive polymers and materials.

Unit V: Polymers in Miscellaneous Specialty Applications I **(7 h)**

Polymers in agricultural applications: green houses, mulches, control release of agricultural chemicals, seed coatings, etc., polymers in construction and building applications, polymer concrete, polymeric materials used in communication applications, polymer selection, property - application relationship of above mentioned polymers, polymers in electronic applications, polymeric adhesives, role of polymers in automobile industry, polymers in oil recovery, polymers in cosmetics and food applications,

Unit VI: Polymers in oil recovery **(7 h)**

Polymers in EOR, role of polymers, mechanism (how polymers enhance oil recovery?), polymer solutions, polymer injectivity, screening criteria, structure–property correlations and the synthetic methods, rheological properties chemical structure correlation, surfactant and hydrogel polymers, water-soluble polymers for enhanced oil recovery, hydrophobically modified polymers, polyacrylamide group and associating polymers, solution rheology, polymer flooding, economic cost and benefits, polymer water flooding process

Reference Books:

1. Lake, L.W. 1989. Enhanced Oil Recovery, 314-353. Englewood Cliffs, New Jersey: Prentice Hall.
2. Sorbie, K.S. 1991. Polymer-Improved Oil Recovery. Glasgow and London: Blackie.
3. Specialty Polymers: Materials and Applications, Faiz Mohammad, I. K. International Pvt Ltd.
4. Review on applications of polymers in pharmaceutical formulations, Darveshwar J. D, Mule M.S, Birajdar S. M., Pharmatutor Pharmacy Infopedia.
5. Polymer waterflooding, PetroWiki, SPE international. (Net source)
6. Industrial Polymers, Specialty Polymers, and Their Applications, Manas Chanda, Salil K. Roy, CRC Press.
7. Biomedical and Pharmaceutical Polymers, Denis J.-P. Labarre, Gilles Ponchel, Christine Vauthier, Pharmaceutical Press, 2011.
8. Polymers in Defence and Aerospace Applications, Smithers Rapra Ltd, 2007.

Elective IV

409372 (3) : Plastic Waste Management

Teaching Scheme:
Lectures: 3 h / week

Examination Scheme:
In Semester: 30
End Semester: 70
Total: 100

Objective:

1. The present syllabus will make students aware of the present day scenario of polymers and its interaction with the environment.
2. To study the various additives and hazardous chemicals used in the polymer industry.
3. Environmental factors affecting polymer stability and vice a versa.
4. Study of recycling and waste management.

Unit I: Introduction (7h)
Contribution of plastics in modern society, polymers: boon or bane, polymers as a replacement to traditional natural resources, biodegradibility, various degradation mechanisms, significance of nonbiodegradability, myths and reality. Vital role of polymers in healthcare and safety.Role of plastics in clean and hygienic packaging, plastic materials for national security, contribution of plastics in automobiles and agriculture, energy conservation due to plastics.

Unit II: Life cycle and alternative technologies (7h)
Life cycle assessment, carbon footprint, control and monitoring pollution, green chemistry, new methods of production of polymers, new feedstock alternative to petroleum, alternative technologies for ecofriendly plastics, OECD, ASTM standards of composting.

Unit III: Polymer additives (7h)
Additives and stabilizers in polymers: single stabilizers to complex systems, phosphate stabilizers in polymers, polymer processing additives, UV absorbers, hazardous chemicals in polymer industry and their handling.

Unit IV: Degradation of plastic (7h)
Polymer degradation: Degradation mechanism, polymer oxidation and antioxidant action, biodegradation in polymers, environmental degradation of polymers, wavelength sensitivity of polymers, lifetime prediction of plastics, behavior of polymers in fire: assessment of combustion behavior, improvement of polymer stability in fire, weathering of polymers, protection of polymer from photooxidation, exploitation of polymer degradation.

Unit V: Biopolymers (7h)
Biopolymers and Biodegradable Polymers: Aromatic constituents occurring in plants and natural environments or as fossil resources, Natural rubber and GuttaPercha, Comparison to synthetic rubbers, Biodegradation of natural rubber and synthetic rubber, Polyesters: Synthesized by organisms: Polyhydroxyalkanoates (PHA), Non-storage PHAs, Poly(malic acid), Medical and pharmaceutical applications, Polysaccharides, Alginates, Cellulose, Chitin, Chitosan, Starch, etc. Polyamides and complex proteinaceous materials synthesized by organisms, Poly(γ-D-glutamate), Cyanophycin, modifications of proteins, Silk proteins, Adhesive proteins, Protein composites, Wool, Collagens and gelatins.

Unit VI: Recycling and waste management (7h)

Recycling and waste management: Individual steps in the process and their purposes, Separation processes in waste minimization, cutting mills, crammer feeder, Toxic material handling and management, Plastic waste management, three R's, reduce, recycling, reuse and recover. Combustion and incineration processes, Polymer Recycling, integrated recycling and compounding, Biotechnological versus chemical recycling, Disposal of waste plastic, specific energy consumption. Energy and feedstock recovery through recycling, Polymers and energy, Future of degradable polymers.

Reference Books:

1. Handbook of polymer degradation, Sec Ed. S Halim Hamid, Marcel Dekker Inc, NY
2. Interaction of Polymers with Polluted Atmospheres, Smithers Information Ltd, September 2009.
3. The Chemistry of Polymers, John W. Nicholson, RSC Publishing
4. Biopolymers, edited by Alexander Steinbüchel, Institute of Microbiology, University of Münster, 2004 by WILEY-VCH
5. Plastics for environment and sustainable development, ICPE, CIPET, Chennai.

409373: Computational Tools in Design and Simulation

Teaching Scheme:
Practical: 2 h/week

Examination Scheme:
TW: 50
Total: 50

To make the students aware of advanced computational tools used in industry, more particularly in the field of product design and simulation.

Students are required to perform **three experiments each** (**total nine**) based on the following three categories.

1. **Introduction to Product design tools:** Introduction to AutoCAD and Working with the Windows Environment: Starting AutoCAD and Understanding the Display, Interacting with AutoCAD, Auto-CAD File Operations, Creating Your First Drawing:Setting up a Drawing, Using AutoCAD Drafting Tools, Understanding Objects, Viewing and Plotting a Drawing:Using ZOOM and PAN To Control the Display**,** Basic CAD Drawing Techniques:Setting the Display Format and Units, Coordinate System Basics**,** Understanding Layers and Line-types:Working with Layers, Understanding and Creating Line-types**,** Creating Basic Geometry:Drawing Rectangles, Drawing Circles, Drawing Arcs, Annotating a Drawing with Text and Hatching:Adding Text to a Drawing, Filling Areas with Hatching, Drawing Accurately:Working with Object Snaps**,** Basic Editing Skills: Deleting and Restoring Objects, Moving, Copying, and Offsetting Objects Rotating, Mirroring, Scaling, and Stretching Objects, Editing Edges and Corners of Objects, Producing Arrays of Objects (ARRAY), Advanced Drawing Techniques:Dividing and Measuring an Object, Dimensioning a Drawing:Dimensioning Basics and Dimensioning with Precision, Linear and Radial Dimensioning, Angular Dimensioning, Editing Dimensions, Modifying Object Characteristics:Changing Object Properties, Extracting Information from your Drawing**,** Using Symbols and Attributes:Defining Groups, Creating Blocks, Adding Information to a Block with Attributes.

2. **Introduction to plastic simulation software:** Introduction- plastic simulation software, applications of plastic simulation software in industries. In tool development and in product design, **Meshing:** Importing model, Types of meshing, quality criteria for mesh, mesh repair tools (merge node, purge node, insert node, global merge), Part Meshing. Operating tools like - rotate, translate, scale and reflect. Creating line, creating node, mesh diagnosis, mesh repair wizard, **Feed system generation:** Feed system design with lines. Feed system design with beam. Feed system design for tapered feed system. Rules for designing feed system, **Material selection:** Material selection, importing new material in to the Library, reading material data base and its property. Setting process parameter for material by using database, **Process parameter setting:** Automatic setting. Manual process parameter setting. Setting packing profile for part. Seceding cooling time and packing time for part. **Cooling channel design:** Cooling channel extraction, Importing Cooling channel, Designing cooling channel, cooling channel wizard. Cooling channel diagnosis, **Analysis Sequence:** Cool, Fill, Pack and Warp Analysis. Optimization of fill, pack and warp analysis, **Results interpretation:** Results interpretation. Use of different commands for results interpretation.

3. **Introduction to Modeling software like UG or CATIA:** Introduction to the Sketcher, Sketcher Geometry Management, Sketcher Geometry Creation, Sketcher Geometry Modification, Sketcher Constraints Creation, Modification of Constraints, Relations between Dimensions, Sketcher Analysis Tools, Performing a quick geometry Diagnosis, Sorting Sketches by their Solving Status, Managing

Sketches. **Part Design:** Introduction to Part Design, Basic Sketch Based Features, Creating Pads, Creating Shafts, Holes, Pockets, Grooves, Rib, Slot, Limiting Features, Sketch Based Features Recommendations, Creating Drafts, Filleting, Variable, Fillet, Face Fillet, Chamfering, Multi section Solids, Combine solids, Duplicating Features, Moving Features, Reordering Features, 3D Wire frame Elements, Creating Pads and Pockets from Surfaces, Surface-Based Features, Creating Ribs and Slots, Creating Stiffeners, Design Using Boolean Operations, Cut, Paste, Isolate, Break, Advanced Drafts, Introduction to Part Analysis, Analyzing Threads and Taps, Draft Analysis, Boolean operations, **Generative Shape Design:** Introduction to Surface Design, The Generative Shape Design Workbench, Surface Design Workbench Terminology, Why Create 3D Wireframe Geometry?, Creating Points in 3D, Lines in 3D, Planes in 3D, Curves in 3D, Managing Geometrical Sets, Creating a Surface Offset from a Reference, Surface from Boundaries, Multi-Section Surface, Joining Elements, Splitting/Trimming, Fillets, Transforming Elements, Extrapolating Elements, Disassembling Elements, Creating Datum Features, Updating a Part, Creating a Connect Curve, Axis, 3D Curve Offset, Multiple Extract, Smoothing Curves, Spine Curve, What is a Blend?, Types of Blends, Multi-Ribbon Shape Fillet, Blending Vertex when Making Fillets, Creating a Conic Blend Surface, Creating a Blend Surface, Blend Surfaces Recommendations, Why do you need to analyze surface geometry?, Healing Surfaces, Advanced Features in GSD, What is a Swept Surface?, Creating a Line Type Swept Surface, Creating a Circle Type Swept Surface, Creating an Adaptive Swept Surface, Advanced Swept Surfaces Recap Exercise, Connect, Draft Analysis, WFS Management Features versus GSD Management Features, Geometrical Sets Recommendations, Working with Hybrid Part, Work on support, Hybrid and non hybrid method of modeling in V5
Options in having a geometrical set in Cat part, working only in a part body.

Assignments:

The students are required to work on three assignments each from the above three categories. (i.e. total nine assignments).

TW Assessment:
The TW will be based on performance of the student during practical and assignments submitted by him/her.

409374: Project Phase II

Teaching Scheme:
Practical: 2 h/week

Examination Scheme:
TW: 50
OR: 100
Total: 150

During the second term the students are required to:

1. Carry out detailed experimental work on previously defined (Phase I) research problem.
2. Write a *Project Report*, which should be broadly divided into the following sections –
    a. Abstract
    b. Introduction
    c. Experimental
    d. Results and Discussion
    e. Conclusion
    f. Plant layout and costing
    g. References

Students should submit a neatly typed and spiral bound *Project Report* at the end of the term in the following format.

Font: Times New Roman, Font size: 12, Headings: 14, Spacing: 1.5, typed on one side of the A4 size paper with proportionate diagrams, figures, graphs, photographs, tables etc.
Referencing style:

1. Guo J. X. and Gray D. G., <u>Chiroptical behavior of (acetyl)(ethyl)cellulose liquid-crystalline solutions in chloroform</u>, *Macromolecules*, *22*, (1989), 2086.

(Reference numbers should be mentioned in the main text as a superscript)

The *Project Report* should contain:

1. The cover page –must mention: Project title, Name of the student(s), Name of the guide, Exam seat number and Year.
2. Certificate from guide
3. Certificate from industry (if any)
4. Index
5. Detailed *Project Report* having sections 'a' to 'g' from above.

The student is required to prepare a month wise work plan (for both semesters) immediately after the allotment of the project and the department is required to maintain a progress report of every student/project. The progress report should reflect monthly progress done by the student as per the work plan. The progress report is to be duly signed by the respective project guide by giving the remarks/marks/grades etc. on the periodic progress done by the student at the mid of the term and should be **submitted along with project report** at the end of respective terms to the examiners as a supporting document for evaluation. Every student will be examined orally based on the topic of his/her project and relevant area to evaluate his understanding of the problem and the progress made by the student during the term.

Each student is required give **presentation** of his work for 10 minutes using 10-12 slides. The presentation will be followed by question answer session of 5 min. Every student will be examined orally for 50 marks based on the topic of his/her project and relevant area to evaluate his understanding of the problem. Term work assessment for 100 marks will be based on student’s workup, performance and progress (depth and quality of work) during the term.

The department should prepare a template of the format of the project report and supply it to the students so as to maintain the uniformity in the project reports.

Students are encouraged to participate and present their project work in various events, competitions, conferences and seminars etc. in consultation with their guide.

Note: The project guides are required to educate the students about antiplagiarism policy of SPPU and apply the same while doing the project.

409366: Introduction to Polymer Industries II

Teaching Scheme: Interaction with industry

Examination Scheme: TW: 25 marks

It is **mandatory** that the students along with the mentor/teacher to visit a large scale Polymer Industry based on various subjects he/she is studied/studying at TE/BE. These may include manufacturing, synthesis, processing, compounding, design, tooling, equipment manufacturing industry and reputed research/testing laboratories etc. to impart thorough industrial exposure and interaction with the industry. Minimum **three types** of industries and/or laboratories to be covered during a visit or two during thesemester.

Students are required to submit neatly typed and spiral bound combined industrial visit report at the end of the term for the purpose of term work assessment. The report should include information about the various aspects and working details of the industry. The student is required to summarize knowledge acquired by her/him during the interactionwith various industries.

The students are required to attach a copy (attested by mentor/teacher) of *Original Attendance Certificate*, to the report mentioning the date of visit issued by the competent authority from the industry where he / she has visited.

The students will be evaluated based on the report submitted, knowledge acquired during the industrial visit at the end of the semester under the head TW for 25 marks.

(Note: As the industrial visit is mandatory the term is not to be granted if any student fails to attend industrial visit.)