Structure and Syllabus of

BE (Polymer Engineering)-2015 Course

w.e.f. 2018-2019

B.E. (Polymer Engineering)-2015 Course
(w.e.f. Academic Year 2018-19)

SEMESTER - I												
Subject Code	**Subject**	**Teaching Scheme Hrs./Week**			**Examination Scheme**					**Total Marks**	**Credits**
		L	**PR / DRG**	**T**	**In-Semester Assessment**	**TW**	**OR**	**PR**	**End Semester Exam**		
409361	Polymer Materials and Compounding	4	2	--	30	--	50	--	70	**150**	**4**
409362	Mold and Die Design	4	2	--	30	--	50	--	70	**150**	**5**
409363	Polymer Processing Operations-II	4	2	--	30	--	--	50	70	**150**	**5**
409364	Elective-I	3	--	1	30	25	--		70	**125**	**3**
409365	Elective-II	3	--	1	30	25	--		70	**125**	**3**
409366	Project Phase-I	--	2	--	--	50	--	--	--	**50**	**2**
409367	Audit Course – 5 (Industrial Training Evaluation**)	--	--	--	--	--	--	--	--	--	--
	Total → (28Hrs.)	**18**	**08**	**02**	**150**	**100**	**100**	**50**	**350**	**750**	**22**
SEMESTER - II											
Subject Code	**Subject**	**Teaching Scheme Hrs./Week**			**Examination Scheme**					**Total Marks**	**Credits**
		L	**PR/ DRG**	**T**	**In-Semester Assessment**	**TW**	**OR**	**PR**	**End Semester Exam**		
409368	Polymer Blends and Composites	4	2	--	30	--	50	--	70	**150**	**4**
409369	Product Design and Polymer Testing	4	2	--	30	--	--	50	70	**150**	**4**
409370	Elective-III	3	--	1	30	25	--	--	70	**125**	**3**
409371	Elective-IV	3	--	1	30	25	--	--	70	**125**	**3**
409372	Computational Tools in Design and Simulation	--	2	--	--	50	--	--	--	**50**	**2**
409373	Project Phase-II	--	6	--	--	100	50	--	--	**150**	**6**
	Total → (28Hrs.)	**14**	**12**	**02**	**120**	**200**	**100**	**50**	**280**	**750**	**22**

Total Number of credits = 22 + 22 = 44

Electives

409364 Elective – I	409365 Elective – II	409370 Elective – III	409371 Elective – IV
A. Polymer Reaction Engineering	A. Specialty Polymers and Applications	A. Polymer Characterization	A. Membrane Technology
B. Fiber Science and Technology	B. Advanced Polymer Synthesis	B. Polymer waste Management	B. Paints and Adhesives
C. Mechanics of Composites	C. Packaging Technology	C. Rubber Technology	C. Polymer Nanotechnology

Important Notes

1. **Abbreviations**
   L: Lecture: Practical, DRG: Drawing, T: Tutorial
   TW: Term work, PR: Practical, OR: Oral
2. ****** Audit course no. 5 (**409367)** will comprise the evaluation of students for the industrial training *carried out between 6th and 7th* semesters.
3. In-Semester Theory examination will be conducted approximately one and half month after the commencement of each semester.
4. In-Semester Theory examination will be based on first three units from Syllabus and will be conducted by the Savitribai Phule Pune University.
5. Total time allotted for In-Semester Theory examination will be 1 hr.
6. Total time allotted for End- Semester Theory examination will be 2 hrs. and thirty minutes.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409361
Course Name: Polymer Materials and Compounding
Credits: 4

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409361	Polymer Materials and Compounding	4	-	2	30	70	--	--	50	**150**

PREREQUISITES

Particle Technology, Design of Equipment and Machine Elements, Polymer Processing Operations-I, Polymer Rheology

COURSE OBJECTIVES

1. To understand the basic mixing mechanisms.
2. To understand fundamentals of mixing, blending and compounding processes of various additives in the polymer.
3. To study various mixing devices with respect to construction and mixing mechanism.

COURSE OUTCOMES

On completion of the course, the students will be able to

1. Demonstrate the ability to understand mixing mechanisms.
2. Demonstrate the ability to understand fundamentals of mixing, blending and compounding processes of various additives in the polymer.
3. Demonstrate understanding of construction and working of mixing machinery.
4. Demonstrate the ability for selection of compounding equipment for a specific application.

COURSE CONTENTS

Unit I: Polymer Mixing and Blending (L 08)

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 (L 08)

Introduction, types and characteristics of compounds – polymer blends, polymer formulations, filled polymers and polymer composites, 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 (L 08)

Polymer compound ingredients, fillers and reinforcements like 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 (L 08)

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 Sections (L 08)

Kneaders, 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 (L 08)

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 co-rotating, conveying characteristics of screw elements & mixing elements, leakage flow equations, solids conveying zone, melting mechanism, residence time distribution.

List of Practical (Expt. No. 1 is compulsory, and any 8 from Expt. No. 2 to 13):

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 internal 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 internal mixer.
8. To study the torque and mixing time for compounding of filled (Talc and $CaCO_3$) polypropylene compositions.
9. Preparation of filled polymers using twin screw extruder.
10. To study power consumption for twin screw compounder.
11. Preparation of master batch – for PVC based cable application.
12. To study compounding and dispersion of carbon black filled compositions.
13. Compounding of rubber

Reference Books:

1. Mixing in Polymer Processing, C. Rawendaal, Marcel Dekker.
2. Principles of Polymer Processing, 2nd ed., Z. Tadmor and C.G. Gogos, Wiley-Interscience, 2006.
3. Polymer Mixing and Extrusion, N.P. Cheremisinoff, Marcel Dekker, 1998

4. Polymer Mixing Technology, G. Mathews, Applied Science, London, 1984
5. Plastics Materials, J.A. Brydson, Jordon Hill, Oxford, 1999.
6. Polymer Mixing Technology and Engineering, J.L. White, A.L. Coran and A. Moet, Hanser Gardner Publications Ltd., USA, 2001.
7. Thermoplastic and Rubber Compounds : Technology and Physical Chemistry, J.L. White and K.J. Kim, Hanser Gardner Publications Ltd., USA, 2007
8. Mixing and Compounding of Polymer : Theory and Practice, 2nd ed., I.M. Zloczwero, Hanser Publications, 2009
9. Understanding Compounding, R.H. Wildi and C.Maier, Hanser Gardner Publications Ltd., USA, 1998.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409362
Course Name: Mold and Die Design
Credits: 5

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409361	Mold and Die Design	4	-	2	30	70	--	--	50	**150**

PREREQUISITES

Engineering Graphics, Machine Design and Drawing, Design of Equipment and Machine Elements, Polymer Processing Operations-I, Polymer Rheology

COURSE OBJECTIVES

1. To understand the constructional features and working of basic elements in injection molds.
2. To understand design of two plate and underfed injection molds.
3. To understand constructional features and working of basic elements hot runner, split cavity injection molds.
4. To understand constructional features and design of extrusion dies.

COURSE OUTCOMES

On completion of the course, the students will be able to Demonstrate the ability to

1. Understand the constructional features and working of basic elements in injection molds.
2. Understand design of two plate and underfed injection molds.
3. Understand constructional features and working of basic elements hot runner, split cavity injection molds.
4. Understand constructional features and design of extrusion dies.

COURSE CONTENTS

Unit I: Constructional features of basic mold elements (L 08)

Types of - locating rings, guide pillars, guide bush, spigotted guide pillars and guide bush; Design features of standard mold components, 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 and ejection systems (L 08)

Cooling system: Bolster cooling systems, insert cooling systems, baffle, bubbler cooling systems, heat rod and heat pipe systems, cooling time calculation, cooling channel layout. 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 III: Underfed, Hot runner molds, split molds and Molds for threaded components (L 08)

Design and constructional features of underfed mold, 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; split and side core molds. Actuation techniques: finger cam, dog leg cam, cam-track actuation, split movement calculations, split safety techniques.

Unit IV: Die Design (L 08)

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 V: Heat Treatment, finishing operations and Metrology (L 08)

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

Unit IV: Flow Analysis (L 08)

CAD/CAM/CAE applications in mould design. 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:

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

Reference Books:

1. Fundamental of Plastic Moulding Design**,** S.K. Nayak, P.C. Padhi and 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 and Y.F. Zang, CRC Press, 2004.
3. How to make Injection Molds, 2nd ed., Menges and Mohren, Hanser Publication, 1986.
4. Dies for Plastics Extrusion, M.V. Joshi, Macmillan India Ltd., 1984.
5. Plastic Molds and Dies, Sors, Bardocz, Radnoti, Von Nostrand Reinhold Company and
1. Akademiai Kiado, 1981
6. Mold Engineering, H. Rees, Hanser Publishers, 1995
7. Plastics Mold Engineering Handbook, J.H. Drebois and W.I. Prible, Von Nostrand Reinhold, 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, 4th ed., R.C.W. Pye, East-west Press Pvt. Ltd.
12. Molding machine and mold for plastic processing, 2nd ed., N. Bossi,1987, publisher: Negri Bossi Spa, 1984

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409363
Course Name: Polymer Processing Operations-II
Credits: 5

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409361	Polymer Processing Operations-II	4	-	2	30	70	--	50	--	**150**

PREREQUISITES

Design of Equipment and Machine Elements, Polymer Processing Operations-I, Polymer Rheology

COURSE OBJECTIVES

1. To understand the fundamentals of polymer processing techniques – thermoforming, blow molding, calendaring and rotational molding.
2. To understand construction and working of the processing equipment.
3. To understand effect of processing parameters on product properties.
4. To understand structure development during processing.

COURSE OUTCOMES

On completion of the course, the students will be able to demonstrate the ability to

1. Understand the fundamentals of polymer processing techniques
2. Understand construction and working of the processing equipment.
3. Understand effect of processing parameters on product properties.
4. Understand structure development during processing.

COURSE CONTENTS

Unit I : Blow Molding (L 08)

Blow moulding – Fundamentals of the process, complete blow moulding operation, accumulator based machines, extrusion blow moulding, injection stretch blow moulding, Blow moulding machines, start-up and shut-down procedures, process control, blow moulding plants, parison wall thickness control, parison swell, parison inflation, cutting devices, process parameters and their effect on product quality control, moulding defects - causes and remedy.

Unit II : Thermoforming (L 08)

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, heat reversion, defects in thermoformed articles and remedies, equipment details.

Unit III : Calendaring (L 08)

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-calendar and post-calendar train, special lines and arrangements, calendared flooring lines, lamination with calendar. Analysis of calendaring – (through put), pressure profile through 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 Molding (L 08)

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: Structure Development during processing (L 08)

Structure and morphology developed during processing techniques like injection, blow molding, rotational molding, etc. Molecular structure required for above processing techniques. Effect of various processing parameters on properties of polymers, and correlation with structure and morphology. 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.

Unit VI : Machining, printing and decoration methods (L 08)

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 metallizing, texturizing, special effects like rainbow effect, hot stamping, embossing.

List of Practicals (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
1. the quality of a rotationally moulded 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 etc.)
11. Rotational moulding of liquid polymers.
12. Study of decorative methods for plastics.

Reference books:

1. Blow Moulding Handbook, R. Rosato and D. Rosato, Hanser Publication, 1989.
2. Applied Rheology in Polymer Processing, 1st ed., B.R. Gupta, Asian Book Pvt. Ltd, 2005.
3. Injection Moulding - Technology and fundamental, M.R. Kamal, A.I. Isayev and S. Liu, Series editor J.L. White, Hanser Publishers, 2009
4. Polymer Processing, J. Mckelvy, John Wiley, 1962.
5. Fundamentals of Polymer Processing, S. Middleman, McGraw-Hill, 1977.
6. Rotational Moulding , R.J. Crawford, Research Press Ltd, 1996
7. Plastic Engineering Handbook of the Society of Plastics Industry, 4th ed., J., Frados, Van Nostrand Reinhold
8. Plastics Engineering, 3d ed., R J. Crawford, Elsevier Publishers, Indian print-2006
9. Technology of Thermoforming, J.L. Throne, Hanser Gardner Pub. Inc., 1996
10. Plastics: Surface and Finish, ed. S.H. Pinner and W.G. Simpson; London Butterworth, 1971
11. Calendaring of Plastics, R.A. Elden and A.D. Swan, London Iliffe Books, 1971
12. Polymer Processing, J. Mckelvy, Wiley, 1962

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409364-A
Course Name: (Elective I-A) Polymer Reaction Engineering
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409364-A	Polymer Reaction Engineering	3	1	--	30	70	25	--	--	125

PREREQUISITES

Mass Transfer and Reaction Engineering, Polymer Materials, Polymer Chemistry, Design of Equipment and Machine Elements

COURSE OBJECTIVES

1. To understand polymerization reactions mechanism and their effect on design of polymerization reactors.
2. To understand distinguishing features and challenges involved in polymer manufacturing processes.
3. To get acquainted with technologies used for manufacturing polymers at commercial scale.

COURSE OUTCOMES

On completion of the course, the students will be able to demonstrate the ability to

1. Understand polymerization reactions mechanism and their effect on the design of polymerization reactors.
2. Understand the distinguishing features as well as the challenges involved in polymer manufacturing processes.
3. Understand technologies used for manufacturing polymers at commercial scale.

COURSE CONTENTS

Unit I : Introduction (L 06)

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 (L 06)

Molecular weight/Molecular weight distribution 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 (L 06)

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: Reactors Systems used for polymer manufacture (L 06)

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 (L 06)

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 (L 06)

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. Fundamentals of Polymer Engineering, 2nd ed., A. Kumar and R.K. Gupta , Marcel Dekker, 2003.
2. Polymerization Process Modeling, N.A. Datson, R. Galvan, R.L. Laurence and M. Tirrel, VCH Publishers, Inc., 1996.
3. Control of Polymerization Reactors, F.J. Schork, P.B. Deshpande and K.W. Leffew, Marcel Dekker, 1993.
4. Reaction Engineering of Step Growth Polymerization, S. Gupta and A., Plenum Press, 1987.
5. Encyclopedia of Polymer Science and Engineering, 2nd ed., John Wiley & Sons, 2005.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409364-B
Course Name: (Elective I-B) Fiber Science and Technology
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409364-B	Fiber Science and Technology	3	1	--	30	70	25	--	--	**125**

PREREQUISITES

Design of Equipment and Machine Elements, Polymer Processing Operations-I, Polymer Rheology, Polymer Materials, Structure-Property Relations

COURSE OBJECTIVES

1. To understand natural and synthetic fibers along with their manufacturing techniques.
2. To understand importance of modification of synthetic fibers to imitate natural fibers.
3. To study the effect of structure of polymer used on the application of fibers.

COURSE OUTCOMES

On completion of the course, the students will be able to demonstrate the ability to

1. To understand various raw materials used in fibre applications.
2. To understand various natural fibers and compare their properties with synthetic fibers.
3. To understand various fiber spinning techniques and post spinning operations.
4. To understand the need for modification and different methods used for modification of fibers.
5. Understanding the dyeing and mass coloration techniques

COURSE CONTENTS

Unit I : Introduction (L 06)

Various terminologies and definitions, classification of fibers, advantages and disadvantages of synthetic fibers over natural fibers, molecular requirements of fiber forming polymers, properties and applications of synthetic and natural fibers; mercerization process, brief introduction to various stages involved in synthetic fiber manufacture, studies of natural fibers-various sources, properties and applications. Raw materials and polymerization techniques used to obtain synthetic fibers, e.g. polyester, polyamide, acrylics, PP, etc.

Unit II : Fiber spinning (L 06)

Spinning techniques used in fiber manufacture along with examples - melt spinning, solution spinning, wet spinning, dry spinning, dry-jet wet spinning, comparison of wet and dry spinning, high speed spinning and its effect on morphology, spin draw processes.

Unit III: Post spinning operations (L 06)

Studies of spin finish: need, function, chemical composition, methods of application, studies of post spinning operations, stretching or drawing of fibers, texturing false twist process, draw texturing, air jet texturing, stuffer box texturing.

Unit IV: Structure development during fiber spinning (L 06)

Staple fiber production process with the steps involved, fiber structure properties and identification, structural changes taking place during spinning, drawing and heat setting and its effect on properties of fibers.

Unit V: Fiber treatment and colouration (L 06)

Mass coloration methods, mass coloration advantages and disadvantages, dyeing of synthetic fibers in loose fiber and yarn form, carrier dyeing, high temperature dyeing, thermosol process, acid and basic dyeing process, types of dyes used for natural fibers, difference between dyes and pigments.

Unit VI: Modification of fibers (L 06)

Modified synthetic fibers, need of modifying synthetic fibers, preparation, advantages and commercially important modified fibers, testing of filament yarns and staple fibers: denier, tenacity and elongation, spin finish content, percent shrinkage.

Reference Books:

1. Fundamentals of Fiber Formation, A. Ziabicki, John Wiley, New York, 1976.
2. High Speed Fibre Spinning, A. Ziabicki and H. Kawari, Krieger Publishing Company, 1991.
3. Production of Synthetic Fibers, A.A. Vaidya, Prentice Hall, India, 1988.
4. Manufactured Fibre Technology, V.B. Gupta and V.K. Kothari , Chapman and Hall, London, 1997.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409364-C
Course Name: (Elective I-C) Mechanics of Composites
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409364-C	Mechanics of Composites	3	1	--	30	70	25	--	--	**125**

PREREQUISITES
Applied Mechanics, Strength of Materials, Polymer Materials, Polymer Chemistry

COURSE OBJECTIVES
1. To study the mechanics of composites at the micro and macro level so as to prepare the students for undertaking design of composites products.
2. To study classical lamination theory and failure theories for laminates.
3. To study product design with composites

COURSE OUTCOMES
On completion of the course, the students will be able to
1. Demonstrate the ability to understand micromechanics and macro mechanics of composites.
2. Demonstrate the ability to understand to design tailor made laminates.
3. Demonstrate the ability to understand test methods for composites.

COURSE CONTENTS

Unit I: Macromechanical Behaviour of lamina (L06)
Stress-strain relations for anisotropic materials, stiffness, compliances and engineering constants for orthotropic materials, restrictions on elastic constants of isotropic and orthotropic material, 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

Unit II: Failure Theories (L 06)
Biaxial strength criteria for an orthotropic lamina: maximum stress failure criterion, maximum strain failure criterion, Tsai-Hill failure criterion, Hoffman failure criterion, Tsai-Wu tensor failure criterion, hygrothermal stresses and strains in unidirectional and angle lamina.

Unit III: Micromechanical (L 06)
Mechanics of materials approach to stiffness i. e. determination of engineering constants for the lamina, Halpin-Tsai equations, elasticity approach to stiffness, particulate composites, mechanics of materials approach to strength, tensile and compressive strength in fiber direction.

Unit IV: Macromechanical behavior of laminate (L06)

Classical lamination theory, laminate code, symmetric laminates, theoretical and experimental cross-ply laminate stiffness, angle-ply laminate stiffness, theoretical and experimental angle-ply laminate stiffness, antisymmetric laminates, nonsymmetric laminates, balanced laminates, quasi-isotropic laminates

Unit V: Design examples and vibration (L06)

Design of sandwich structures, design of tension members, compression members, torsional member, beam design, laminate joint - bonded and mechanical, design of composite bolted joints, 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

Unit VI: Testing (L 06)

Various tests for compressive and tensile properties - fixtures and methods, three point and four point bending, flexural test methods, in-plane shear test methods like ± 45 shear test, 10° off axis test, Iosipescu shear test, two-rail and three-rail shear tests, inter-laminar shear strength, fatigue tests, pin bearing properties, damage identification using nondestructive evaluation techniques: ultrasonic, acoustic emission, X-radiography, thermography, laser shearography.

Reference Books:

1. Mechanics of Composite Material, R. Jones, McGraw Hill Company, 1975.
2. Fibre Reinforced Composites, P.K. Malik, Marcel Dekkar, 1988.
3. Mechanics of Composite Materials, 2nd ed., A.K. Kaw, CRC Press, 2005.
4. Analysis and Performance of Fiber Composites, 3rd ed., B.D. Agarwal, L.J. Broutman and K. Chandrashekhara, John Wiley & Sons Inc, 2006.
5. Mechanics of Composite Materials and Structures, M. Mukhopadhyay, Universities press (India) Pvt. Ltd., 2004.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409365-A
Course Name: (Elective II-A) Specialty Polymers and Applications
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409365-A	Specialty Polymers and Applications	3	1	--	30	70	25	--	--	125

PREREQUISITES
Polymer Materials, Polymer Chemistry, Polymer Structure property relationship

COURSE OBJECTIVES
1. To impart knowledge about synthesis, structure-property relationship of novel polymeric materials.
2. To impart knowledge about relating the structure-property to innovative applications of specialty polymers.

COURSE OUTCOMES
1. Demonstrate the ability to understand unusual properties of materials, various sensory-stimulus response of materials, develop understanding of properties of advanced materials leading to novel applications.
2. Demonstrate the ability to understand intricate balance of properties, performance, sustainability and economy of materials as exhibited in nature, which will act as a guiding principle in designing specialty material.
3. Demonstrate the ability to understand the structure-property and correlation between molecular requirements to satisfy the property requirement. It will lead him/her to design material and its formulation, which will encompass various aspects such as synthesis, characterization and testing of representative materials.

COURSE CONTENTS

Unit I : Liquid Crystalline polymers (L 06)
Introduction, history, structural requirements, types of liquid crystalline (LC) phases and 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 (L 06)
Theory of conduction, semi-conductors and conducting polymers, 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, electrochemomechanical devices, coating, etc.

Unit III : Heat and fire resistant polymers (L06)

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, PBT, PBO, PBI, PPS, PPO, PEEK, chlorinated polymers, engineering plastic blends.

Unit IV : Smart polymers (L 06)

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 polymers (L06)

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 IV: Miscellaneous Polymers (L 06)

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. Handbook of Thermoplastics, O. Olabisi, Marcel Dekker Inc., 1997.
2. Polymers for High Technology - Electronics and Photonics, M.J. Bowden and S.R. Turner, American Chemical Society, 1987.
3. High Modulus Polymer - Approaches to Design and Development, A. Zachariades and R.S. Porter, Dekker Publication, 1988.
4. Polymers for Space Research, C.L. Segal and F.N. Kelly, Marcel Dekker, 1970.
5. Engineering Polymers, R.W. Dyson, Chapman Hall, NY, 1990.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409365-B
Course Name: (Elective II-B) Advanced Polymer Synthesis
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409365-B	Advanced Polymer Synthesis	3	1	--	30	70	25	--	--	125

PREREQUISITES
Polymer Materials, Polymer Chemistry, Polymer Structure property relationship

COURSE OBJECTIVES
1. To impart the awareness of recent advances in polymer material synthesis at National and International level.
2. To impart the awareness of synthesis techniques of specialty polymers.

COURSE OUTCOMES
The student will demonstrate understanding of
1. Recent advances in polymer material synthesis.
2. Synthesis techniques of specialty polymers.

COURSE CONTENTS

Unit I : Polymerization techniques (L 06)
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 (L06)
Ring opening metathesis polymerization (ROMP), ring forming polymers, living cationic and radical polymerization, metal catalyzed olefin polymerization, cyclopolymerization, oxidative polymerization, dispersion polymerization, mini-dispersion polymerization, microbial synthesis of polymers, template polymerization

Unit III : Synthesis of Specialty Polymers (L06)
Synthesis of silicones, polyphosphazenes, polythiazyl, polybenzimidazole, polybenzoxazole, polybenzthiazole, Rubbers: silicones, epichlorohydrin, fluoroelastomers, polysulphides, polyurethane, acrylic rubbers, silane-containing polymers.

Unit IV: Branched and Dendritic Polymers Synthesis (L06)
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 (L 06)

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, supramolecular and metallo-supramolecular polymers and their applications.

Unit I: Frontiers in Polymer Synthesis (L 06)

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. Core Concepts in Supramolecular Chemistry and Nano-chemistry, 1st ed., J W Steed, Wiley.
2. New Frontiers in Polymer Synthesis, ed. S. Kobayashi, Springer.
3. Self-Assembly and Nanotechnology Systems: Design, Characterization, and Applications, Y.S. Lee, John Wiley & Sons, Inc., 2012
4. Supramolecular Chemistry, J.W. Steed and J.L. Atwood, John Wiley & Sons, 2009
5. Specialty Polymers: Materials and Applications, F. Mohammad, I.K. International Pvt. Ltd, 2007.
6. Principles of Polymerization, 4thedition, G. Odian,, Wiley-Interscience, 2004

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409365-C
Course Name: (Elective II-C) Packaging Technology
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409365-C	Packaging Technology	3	1	--	30	70	25	--	--	**125**

PREREQUISITES

Polymer Materials, Structure-Property Relationship, Polymer Processing Operations, Polymer Rheology

COURSE OBJECTIVES

1. To introduce the students to polymers used in packaging applications
2. To impart knowledge regarding various aspects of package design, materials selection, materials used and their evaluation
3. To study the machinery used in packaging sector

COURSE OUTCOMES

On completion of the course, the students will develop

1. Demonstrate the ability to select a suitable material for relevant packaging application.
2. Demonstrate the ability to create suitable packaging design for a given application.
3. Demonstrate the ability to understand packaging management.

COURSE CONTENTS

Unit I : Introduction (L 06)

Historical background, Need and purpose of packaging, types of packaging, definition of packaging as an integral part of production & marketing. Basic concepts Physical & Physico-chemical such as colligative properties, gas laws, surface tension, dialysis, diffusion, energy measurements, etc. Package – components, separations, clearance, support, positioning, cushioning, weight distribution, suspension & closures.

Unit II: Characteristics of packaging (L06)

Physical characteristics of product – physical state, weight, fragility, rigidity, surface finish, etc. Physico-chemical characteristic – susceptibility to water, water vapour, gases, odour, heat, light, mechanism of spoilage. Compatibility – permissible plasticizers in plastics and coating media, their migration to food – can lining compounds and lacquers for containers for fruit & vegetables, fish, meat & other products. Package design – factors influencing design / product package relationship.

Unit III: Raw material selection criteria (L06)

Materials used, Advantages and limitations of various polymers such as polyolefins, PVC, styrenics, PET, nylon, EVA, etc.

Unit IV: Package Designing (L06)

Product–packaging relationship, product–package characteristics, compatibility factors, product type vs packaging requirements, product characteristics– physical state, centre of gravity, size/weight, volume. product characteristics–chemical: effect of gases, moisture, atmospheric gases, product characteristics – biological: sensitivity to microbial factors. Product characteristics – physico chemicals: effect of moisture, vapor, oxygen & other gases. Cutting, sealing, welding, adhesive bonding, Printing, metallizing, embossing, labeling, painting, lacquering, foil in lay molding, hot stamping

Unit V: Packaging Material Evaluation (L06)

Physical and mechanical properties: weight, dimensions, Mechanical properties - stiffness, tear, tensile, etc., Chemical properties - alkalinity, acidity, resistance, Biological properties, sensitivity to microbes, chemicals, presence of chloride, sulphate, lignin, ash, flammability, Physiological properties – odor / flavours, General test methods, drop tests, stack test, load test, vibration test, Testing of flexible films, Indian standard for food containers

Unit VI : Packaging machinery (L06)

Bottle filling lines which includes bottle washing, sterilization, filling, screw capping/crown corking, induction sealing, labeling etc., form fill seal machines: types (vertical & horizontal), flow rap machine, retort machine, tetra packs, wooden packaging, miscellaneous packaging technique, bag in box, child resistance pack, packaging in canes etc., biodegradable and eco-friendly packaging, advantages and disadvantages, packaging used for export, advancements and developments.

Reference books:

1. Fundamentals of Packaging Technology, F.A. Paine, Blackie & Sons Publication, 1967
2. Packaging, Materials and Containers, F.A. Paine, Blackie & Sons Publication, 1967.
3. Plastics in Packaging, A.S. Athalye, Tata McGraw Hill, New Delhi, 1992
4. Plastic Packaging, S.E.M. Selke, Hanser Gardner Publication, 2004
5. Plastics Packaging – Properties, Processing and Applications, 2nd ed., S.E. M. Selke, John Culter, 2010.
6. Plastics Materials for Packaging, Barnetson, Rapra Publications, 1996
7. Rigid Plastics Packaging – Materials, Processes and Applications, F. Hannay, Rapra Publications, 2002.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409366
Course Name: Project Phase I
Credits: 2

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409366	Project Phase I	--	--	2	--	--	50	--	--	**50**

Course Objectives:

1. The student should be able to choose and evaluate the problem based on current interest of research at national and international level.
2. To train the student to carry out literature survey and identify gaps in literature.
3. To develop analytical ability.
4. To train the students to make use of available resources and to procure the resources to carry out his/her project work.

Course Outcomes :

The students will demonstrate the ability to

1. Conduct an independent research project under supervision.
2. Adhere to responsible laboratory or field practice regarding data collection and recording.
3. Of identification of a research project, development of an experimental design, collection of accurate and precise data, critical analysis and interpretation of results, retrieval of information, and critical reading of scientific literature.
4. Prepare a report based on literature survey and present a seminar on the results of a research project.

Course Contents

PROJECT WORK:

The project work shall be based on the knowledge acquired by the student during the coursework and preferably it should meet and contribute towards the needs of the society. The project aims to provide an opportunity of designing and building complete system or subsystems based on area where the student likes to acquire specialized skills.

Project Work Stage – I

Project work Stage – I is an integral part of the project work. In this, the student shall complete the partial work of the project which will consist of problem statement, literature review, project overview. The student shall submit the duly certified progress report of Project work Stage-I in standard format for satisfactory completion of the work by the concerned guide and Head of the Department/Institute.

Important instructions:

1. The candidate is required to work on Original Topic.
2. It should not be the repetition earlier reported work.
3. The student is required to carry out broad literature survey in the area of work.

4. The justification for selection of project topic and originality of the topic is to be mentioned in the Project Report.
5. The student will make presentation of his project work for assessment purpose.
6. All supporting documents, samples, products, soft copies to be preserved and presented at the time of examination, if required.

Term Work Assessment :

The evaluation of students should be based on submitted project report, understanding of the project problem and the work carried out during semester.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409368
Course Name: Polymer Blends and Composites
Credits: 4

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409368	Polymer Blends and Composites	4	-	2	30	70		--	50	**150**

PREREQUISITES

Polymer Materials, Structure-Property Relations, Compounding and Processing Operations.

COURSE OBJECTIVES

1. To impart understanding of various basic requirements like matrix, reinforcing fillers and additives etc. in composite manufacturing.
2. To impart techniques of composite manufacturing.
3. To impart understanding of various Polymer Blends and alloys
4. To impart the knowledge of various standard methods of blend compatibilization

COURSE OUTCOMES

On completion of the course, the students will be able to
1. Demonstrate understanding of properties of thermoplastic, thermosetting matrix resins and different types of fibres and their application.
2. Demonstrate understanding of composites manufacturing techniques.
3. Demonstrate understanding of science of polymer blending and blend morphology

COURSE CONTENTS

Unit I: Introduction to blends (L 08)

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. Lattice theory, entropy of mixing, heat of mixing,

Unit II: Compatibilization and Phase Morphology (L 08)

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 III: Rheology and Interpenetrating Polymer Networks (L 08)

Rheological properties of polymer blends, rheological criteria, interfacial criteria, synergy & additivity, log- and 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.

Unit IV: Fundamentals of Composites (L 08)

Definitions and fundamentals of polymer composites. Short fiber, long fiber, and particulate and nano composites. Different types of reinforcement and matrices used in composites glass fiber, carbon fiber, aromatic polyamide fibers, HWWHDPE fibers, natural fibers. Use of adhesion promoters. Relevant thermoplastic and thermo set matrices. Role of mould release agent.

Unit V: Processing and Tooling (L 08)

Methods of manufacturing fiber reinforced composites such as hand lay-up, spray lay-up, pultrusion, resin transfer, filament winding vacuum bagging, prepeg moulding. Tooling used in composites. Effect of process parameters on end properties.

Unit VI: Applications, troubleshooting of Composites (L 08)

Applications of FRP, trouble shooting and repair of composites. Sandwich structures and cellular structure. Nano composites. Various kinds of nanofillers used in thermoplastic and thermoset matrices. Properties and applications of nano composites.

Reference Books:

1. Polymer Blends, D.R. Paul and Newman,
2. FRP Technology, R.A. Weatherhead, Applied Science Publishers, London.
3. Fiber Reinforced Composites, P.K. Mallide, Marcel Dekker Inc., New York.
4. Plastics Engineering Handbook, J.L. Frados, Van Nostrand Reinhold Co., NY.
5. Polymer Alloys and Blends, Folkes,.
6. Polymer Alloys and Blends: Thermodynamics and Rheology, L.A. Utracki, Hanser Publishers, New York.

Suggested List of Laboratory experiments (Any 08 experiments from the following list):

1. Study of different techniques for blend preparation, and criteria for selecting blend components.
2. Preparation of thermoplastic polymer blend via melt blending.
3. Preparation of polymer blend via solution casting or by latex blending.
4. Preparation of blend interpenetrating polymer networks methodology.
5. Preparation of filled polymer blends.
6. Study of different types of reinforcements and polymer matrices used in composite.
7. Study of formulations for epoxy, unsaturated polyester, vinyl ester resins, and accessories used for the manufacture of FRP laminates.
8. Preparation of particulate filled FRP.
9. Preparation and characterization of single layered configurations of isotropic, orthotropic lamina.
10. Preparation and characterization of symmetric laminates.
11. Preparation and characterization anti-symmetric laminates.
12. Preparation and characterization non-symmetric laminates.
13. Preparation of Natural Fiber Reinforced Thermoplastic or Thermoset Composites.
14. Preparation of Thermoplastic Fiber Reinforced Composites.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409369
Course Name: Product Design and Polymer Testing
Credits: 4

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409369	Product Design and Polymer Testing	4	-	2	30	70	--	50	--	**150**

PREREQUISITES

Polymer Materials, Structure-Property Relations, Mould and Die Design, Strength of Materials, Design of Equipments and Machine Elements

COURSE OBJECTIVES

1. To understand polymer testing techniques related to short term as well as long term mechanical properties.
2. To study thermal and electrical properties.
3. To study various basic concepts in product design
4. To study the design aspect of various specialized products and profiles.
5. To introduce students to modeling and computer simulation.
6. To study the influencing factors such as material selection, processing techniques, design feature etc. on product design.

COURSE OUTCOMES

On completion of the course, the students will be able to

1. Demonstrate understanding of importance of test standards.
2. Demonstrate understanding of test methods.
3. Demonstrate understanding of factors influencing polymer product design.

COURSE CONTENT

Unit I : Product Design Overview (L 08)

Procedure and steps in product design, sequential engineering approach, concurrent or parallel engineering approach to product design, pseudo-elastic design method, application of creep curves, stress relaxation, isometric curves in plastic product design, design considerations for injection molded components - design considerations for bosses, corners, ribs, hinges, considerations for bearing in plastics, life cycle assessment.

Unit II : Design Parameters and Computer Aided Design (L 08)

Fabrication techniques in plastics: Press Fit, Snap Fit, molding considerations in snap fits and press fits, types of adhesives, design of joints for bonding adhesives, screws and fasteners, additive manufacturing techniques.

Unit III : Mechanical and Thermal Properties (L 08)

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: Miscellaneous Test Methods (L 08)

Permeability properties: sorption, diffusion and permeation, analytical tests: determination of specific gravity, density by density gradient method, bulk density, moisture absorption, particle size analysis, nondestructive 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 (L 08)

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 (L 08)

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.

Reference Books :

1. Plastics Part design for Injection Moulding, R.A. Malloy, Hanser Publications, 1994
2. Handbook of Plastics Testing Technology, 2nd ed., V. Shah, John Wiley and Sons Inc., New York, 2008
3. Handbook of Plastics Testing and Failure Analysis, 3rd ed., V. Shah, John Wiley and Sons Inc., New York, 2007
4. Plastics Engineered Product Design, 1st ed., Rosato and Rosato, Elsevier Science, 2003
5. Understanding Plastics testing, D.C. Hilton, Hanser Gardener Publications Inc., 2004
6. Plastics testing and characterization: Industrial applications, A. Naranjo, M. Noriega, T. Osswald, A. Roldan-Alzate and J.D. Sierra, Hanser Gardener Publications Inc.,2008
7. Handbook of Polymer Testing: Physical Methods, R. Brown, CRC press, 1999

Suggested List of Laboratory experiments (Any 08 experiments from the following list):

1. To determine the tensile strength and percentage elongation of film in machine/longitudinal and transverse direction.
2. To determine the tensile strength at break and yield, and % elongation of dumbbell shaped specimens of various polymers.

3. To determine the Izod impact strength of various polymers.
4. To determine the falling dart impact strength for films.
5. To determine the heat deflection temperature.
6. To determine the Vicat softening temperature.
7. To determine the coefficient of friction of films.
8. To determine the specific gravity of rubber sample and other polymeric samples.
9. Study of volume and surface resistivity and to determine the same experimentally.
10. To find out environmental stress crack resistance of polyethylene and other polymeric samples.
11. To carry out water absorption test for various polymers.
12. Determination of burst strength of pipes and determination of pressure rating of pipes.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409370-A
Course Name: (Elective III-A) Polymer Characterization
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409370-A	Polymer Characterization	3	1	--	30	70	25	--	--	125

PREREQUISITES

Polymer Materials, Structure-Property Relations, Polymer Chemistry, Applied Physics, Engineering Chemistry

COURSE OBJECTIVES

1. To study the various characterization techniques based on Spectroscopy, Diffraction, Thermal Analysis, Chromatography, etc.
2. To develop ability to interpret the data obtained from these techniques

COURSE OUTCOMES:

On completion of the course, the students will be able to

1. Demonstrate the ability to understand fundamental principles underlying the various characterization techniques
2. To demonstrate the ability of interpreting the data obtained by various characterization techniques

COURSE CONTENTS

Unit- I : Fourier Transform Infra-red Spectroscopy (FTIR) (L06)

Molecular vibrations, basic theory of Fourier transform spectroscopy, interferrogram, 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 : Nuclear Magnetic Resonance (L06)

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 (L06)

Separation techniques – Gel permeation chromatography (GPC), high-performance liquid chromatography (HPLC), molecular weight and molecular. weight 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 (L06)

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 (L06)

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 (L06)

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.

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, NY, 1989.
5. Textbook of Polymer Science,-F.W. Billmeyer, Wiley-Interscience, 1984.
6. Molecular Motions in High Polymers, R.T. Crompton, Pergmon Press, NY, 1989.
7. The Identification of Plastic and Rubber, K.J. Saunders, Chapman and Hall, London, 1966.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409370-B
Course Name: (Elective III-B) Polymer Waste Management
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Drg.	In Sem.	End Sem.				
409370-B	Polymer Waste Management	3	1	--	30	70	25	--	--	125

PREREQUISITES

Polymer Chemistry, Polymer Materials, Structure-Property Relations, Polymer Processing

COURSE OBJECTIVES

1. To understand the need for polymer waste management and recycling
2. To study various routes for waste management

COURSE OUTCOMES:

On completion of the course, the students will be able to

1. Demonstrate the ability to understand and implement various techniques of polymer waste management
2. Demonstrate the responsibility towards environment

COURSE CONTENTS

Unit- I : Introduction (L06)

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 (L06)

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 (L06)

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 (L06)

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 (L06)

Biopolymers and Biodegradable Polymers: Aromatic constituents occurring in plants and natural environments or as fossil resources, Natural rubber and Gutta Percha, 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(-D-glutamate), Cyanophycin, modifications of proteins, Silk proteins, Adhesive proteins, Protein composites, Wool, Collagens and gelatins.

Unit – VI : Recycling and waste management (L06)

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, 2nd ed., S.H. Hamid, Marcel Dekker Inc., NY
2. Interaction of Polymers with Polluted Atmospheres, Smithers Information Ltd, September 2009.
3. The Chemistry of Polymers, J.W. Nicholson, RSC Publishing
4. Biopolymers, ed. A. Steinbüchel, Wiley-VCH, 2004
5. Plastics for Environment and Sustainable Development, ICPE, CIPET, Chennai.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409370-C
Course Name: (Elective III-C) Rubber Technology
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409370-C	Elastomer and Rubber Technology	3	1	--	30	70	25	--	--	125

PREREQUISITES

Polymer Chemistry, Polymer Materials, Structure-Property Relations, Polymer Rheology, Polymer Compounding

COURSE OBJECTIVES

1. To study the details pertaining to raw materials and formulations of rubbers/elastomers.
2. To study the aspects of processing, testing and applications elastomers.
3. To equip the students with in-depth knowledge for their careers in relevant industry elastomers.

COURSE OUTCOMES

On completion of the course, the students will be able to
1. Demonstrate understanding of basic principles of rubber elasticity.
2. Demonstrate understanding of rubber formulations for specific applications.
3. Demonstrate understanding of processing and testing of rubbers.

COURSE CONTENT

Unit I : Introduction to Rubber Elasticity (L 06)

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 (L 06)

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, nonreinforcing, 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 (L 06)

Vulcanization by sulphur, peroxides and by other methods. Kinetics of vulcanization, chemical reactions, factors affecting rate of vulcanization. Other Rubbers : Tetrafluoroethylene-propylene Rubbers, Polyphosphazene elastomers, Polynorboromene, Polypentenamer, Carboxylated Rubbers, Polyalkalynes, Polytetrahydroduran, Nitroso- and Traizine Elastomers.

Unit IV: Machinery (L 06)

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 and Testing Equipments, mould and die design consideration for rubber products.

Unit V: Manufacturing of Rubber from Monomers and Other Products (L 06)

Technology used to 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 (L 06)

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. Rheometers for rubber-oscillating disk rheometer, moving die rheometer, Mooney viscometer, Plastometer, Curometer, etc.

Reference Books :

1. Rubber Technology, ed. M. Morton, Kluwer Academic Publishers, 2010
2. Rubber Compounding Chemistry and Application, 1st ed., B. Rodgers, CRC Press, 2004
3. Rubber Compounding, F.W. Barlow, Mercel Dekker Inc., 1993
4. The Physics of Rubber Elasticity, L.R.G. Treloar, Oxford University Press Inc, 2005
5. Natural Rubber Science and Technology, A.D. Roberts, Oxford Science Publication, 1988
6. Engineering with Rubber: How to design Rubber components, A.N. Gent, Hanser Publishers, 2001
7. Practical Rubber Compounding and Processing, B.W. Evans, Applied Science Publication, 1981
8. Rubber Technology and Manufacture, 2nd ed., C.M. Blow, Butterworth-Heinmann, 1982
9. Handbook of Elastomers, 2nd ed., ed. A.K. Bhowmick and H.L. Stephens, Mercel Dekker, Inc., (2001)
10. Rubber Products Manufacturing Technology, 1st ed., A.K. Bhowmick, CRC Press, 1994

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409371-A
Course Name: (Elective IV-A) Membrane Technology
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409371-A	Membrane Technology	3	1	--	30	70	25	--	--	125

PREREQUISITES

COURSE OBJECTIVES

1. To impart knowledge of designing of membranes and preparation of membranes.
2. To impart knowledge of transportation theories in membranes and their applications.

COURSE OUTCOMES

On completion of the course, the students will be able to

1. Understand the significance of membrane processes
2. Synthesize and Characterize various membranes for specific applications
3. Understand the different membrane modules
4. Understand the impact of membrane processes on the society including environment, health and ecosystem.

COURSE CONTENTS

Unit I : Introduction and Fundamentals of Membranes (L 06)

Introduction and classification of Membrane Processes, Factors affecting the separation processes, Merits and Demerits of Membrane Processes

Unit II : Membrane Material and their Properties (L 06)

Polymer membrane, Inorganic Membranes, Biological membranes, Effect of polymeric structure on Tg, Glass transition temperature depression, Thermal, Chemical and Mechanical Properties.

Unit III : Synthetic Membranes (L 06)

Synthetic Membranes Preparation, Phase inversion Membranes, Composite Membranes, Inorganic Membranes Influence of various parameters on Membrane morphology

Unit IV: Characterization of Membranes (L06)

Characterization of Porous Membranes, Characterization of Ionic membranes, Characterization of nonporous membranes

Unit V: Transport in Membranes and Membrane Reactors (L 06)

Transport through porous membranes, non-porous membranes, ion-exchange membranes, Membrane Reactors and membrane Bioreactors, Applications of membranes in Gas Separation and water purification.

Unit VI : Polarization and Fouling Phenomena in Membranes (L 06)

Boundary layer film model, concentration polymerization in liquid separation and gas separation processes, temperature polarization, membrane fouling, methods to reduce fouling, membrane cleaning, Membrane modules.

Books:

1. Mulder, J., Basic Principles of Membrane Technology, Springer, 1996
2. Noble R. D., Membrane Separation Technology: Principles and Applications, Elsevier, 1995
3. Ricci L., Separation techniques, McGrawHill publications, 1980
4. Baker R. W., Membrane Technology and Applications, 2nd edition, Wiley, 2004.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409371-B
Course Name: (Elective IV-B) Paints and Adhesives
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409371-B	Paints and Adhesives	3	1	--	30	70	25	--	--	125

PREREQUISITES

Particle Technology, Polymer Materials, Polymer Chemistry, Structure-Property Relations, Polymer Compounding

COURSE OBJECTIVES

1. To give a broad view of coatings, their types, formulation and various areas of application
2. To emphasize on eco-friendly paints and green technology.
3. To study the evaluation techniques in-depth in paint manufacture and quality control.
4. To study fundamentals of adhesion including theories, types, surface science, joint design.
5. To study formulations for various applications and their application methods
6. To study the evaluation of formulations and adhesive joints.

COURSE OUTCOMES

On completing the course, student will demonstrate ability to
1. Demonstrate the ability to understand formulations of paints and coatings.
2. Demonstrate the ability to understand evaluation of paints and coatings.
3. Understand basic principles, classification and theories of coating and adhesion.
4. Understand relevance of surfaces characteristics and various pretreatments required.
5. Understand role of ingredients in adhesive formulation.

COURSE CONTENTS

Unit I : Introduction and Formulations (L 06)

Classification, basic terminology used, mechanism of film formation; raw materials, additives and their properties; solvents and their properties; various steps in manufacturing, typical formulations, general properties of paints, varnishes and lacquers; adhesion and cohesion properties, factors affecting adhesion, wetting power, physical, chemical and mechanical properties of paints and coatings. Surface preparation, application of coatings by automatic film applicator and bar applicator.

Unit II : Manufacturing (L 06)

Paint and coating manufacturing machinery such as ball mill, sand mill, attritor mills, Drais mill, basket mill, kaddy mills, twin shaft dispenser, alpine mills; horizontal v/s vertical mills. Manufacture of powder coatings, dry distempers, cement paints, oil based distempers and paints, putties, manufacturing of alkyds, emulsions and hard resins, filtration of resins, paints, solvent emission, recovery and disposal, environmental, health and safety issues.

Unit III : Evaluation and testing, Applications (L 06)

Marine environments, road marking paints, automotive protection, electro-deposition coatings, coatings for high temperature, coatings for aerospace and aircrafts, electrical conducting coatings, thermal sensitive paints, coatings and paints for plastics; special effect pigments (IR reflective, anticorrosive, pearlescent etc.), radiation curable coating, ecofriendly coatings.

Unit IV: Fundamentals and Introduction of Adhesion (L 06)

Theories of adhesion; Functions of adhesives; Advantages and disadvantages of adhesive joints; Checklist factors for adhesive selection; Properties important for adhesion; Basis for bond design. Fundamental forces; Surface forces; Work of cohesion and adhesion; Measurement of surface energy and related parameters; Surface characteristics and preparation of surfaces; Types of stress; Methods of improving joint efficiency; Joint design criteria

Unit V: Adhesives/sealants, Formulations and Applications (L 06)

Principles of adhesion and formulations; Classification/types; Structural and Non-structural adhesives; Elastomers based adhesives; Thermoplastics and pseudo-thermoplastics adhesives; Adhesion in biological systems; Formulation ingredients/additives; Application areas – transportation, medical, construction, etc.

Unit VI: Equipment for Application, Evaluation of formulation and Adhesive bond (L 06)

Mixing, Metering, Coating or Applying the Adhesives; Methods of adhesive application; Joint assembly methods; Bonding equipments.

Failure modes; Testing – tensile, shear, flexural, peel, cleavage, creep, fatigue, impact, durability, aging, biodeterioration, non-volatile content, tack, curing, viscosity, water/moisture absorption; Non-destructive testing

Books:

1. Paints and Surface coatings, 2nd ed., R. Lambourne and T.A. Strivens, Woodhead Publication, 1999.
2. Surface Coatings, Oil and Colour Chem. Association, Volume I and II, Springer science + Business media, 1993.
3. Paint Technology Manuals, Oil and ColorChemists' Association, Volume I, II, III andVI. Chapman and Hall, 1969.
4. DattaP. K. and Gray J. S, Surface Engineering Fundamentals of coatings, VolumeI, Royal Society of London, 1993.
5. DattaP. K. and Gray J. S, Surface Engineering Fundamentals of coatings, VolumeII, Royal Society of London, 1993.
6. Datta P. K. and Gray J. S, Surface Engineering Process Technology and Surface Analysis, Volume III, Royal Society of London, 1993.
7. Pocius A.V., "Adhesion and Adhesives Technology : An Introduction", 2nd ed., Hanser Publishers (2002)
8. Ebnesajjad S. and Landrock A.H., "Adhesives Technology Handbook", 3rded., William Andrew, Elsevier (2014)
9. Skeist I., "Handbook of Adhesives", 3rded.,Van Nostrand, New York (1990)
10. Cognard P., "Adhesives and Sealants : General Knowledge, Application Techniques, New Curing Techniques", Handbook of Adhesives and Sealants, vol. 2, Elsevier (2006)
11. Cognard P., "Adhesives and Sealants : Basic Concepts and High Tech Bonding", Handbook of Adhesives and Sealants, vol.1, Elsevier (2005)
12. Petrie E., "Handbook of Adhesives and Sealants", McGraw-Hill (2006)
13. Mittal K.L. andPizzi A.,"Handbook of Sealant Technology",CRC Press (2009)

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409371-C
Course Name: (Elective IV-C) Polymer Nanotechnology
Credits: 3

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
409371-C	Polymer Nanotechnology	3	1	--	30	70	25	--	--	125

COURSE OBJECTIVES

COURSE OUTCOMES

On completion of the course, the students will be able to

Unit I: Introduction (L 06)

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 of Nanomaterials (L 06)

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 highpurity 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 (L 06)

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 (L 06)

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 (L 06)

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 VI: Properties of Nanomaterials (L 06)

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.

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, G. Louis Hornyak, Joydeep Dutta, Harry F. Tibbals and Anil K. Rao, CRC Press, 2008
5. Ashby, Michael F., Ferreira, Paulo J., Schodek, Daniel L., 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, McGraw-Hill Companies, Inc., 2010.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409372
Course Name: Computational Tools in Design and Simulation
Credits: 2

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
309372	Computational Toole in Design and Simulation	-	-	2	--	--	50	--	--	**50**

PREREQUISITES

Design of Equipment and Machine Elements, Polymer Processing Operations-I, Polymer Rheology, Polymer Materials, Structure-Property Relations

COURSE OBJECTIVES

To make the students aware of advanced computational tools used in the polymer industry, especially in the field of product design.

COURSE OUTCOMES

On completion of the course, the students will be able to

COURSE CONTENTS

Students are required to perform minimum three experiments each based on the following three categories.

1. Introduction to Product design tools
2. Introduction to AutoCAD: hands on experience on all the drafting tools of AutoCad
3. Introduction to plastic simulation software; fill analysis, packing analysis, cooling and warpage analysis.
4. Introduction to Modeling software like UG or CATIA:, hands on experience on all the drafting tools of AutoCad

Assignments:

The students are required to work on minimum three assignments each from the above three categories.

Term Work Evaluation :

Term work assessment will be based on performance of the student during practical and assignments submitted.

B.E. (Polymer Engineering) - 2015 Course
Course Code: 409373
Course Name: Project Phase - II
Credits: 6

Code	Subject	Teaching Scheme (Weekly Load in hrs.)			Examination Scheme (Marks)					
					Theory		TW	PR	OR	Total
		Lect.	Tut.	Pract.	In Sem.	End Sem.				
309373	Project Phase-II	-	-	6	--	--	100	--	50	**150**

Course Objectives:

5. The student should be able to choose and evaluate the problem based on current interest of research at national and international level.
6. To train the student to carry out literature survey and identify gaps in literature.
7. To develop analytical ability.
8. To train the students to make use of available resources and to procure the resources to carry out his/her project work.

Course Outcomes :

The students will demonstrate the ability to

5. Conduct an independent research project under supervision.
6. Adhere to responsible laboratory or field practice regarding data collection and recording.
7. Of identification of a research project, development of an experimental design, collection of accurate and precise data, critical analysis and interpretation of results, retrieval of information, and critical reading of scientific literature.
8. Prepare a report based on literature survey and present a seminar on the results of a research project.

COURSE CONTENTS

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 work
   d. Results and Discussion
   e. Conclusion
   f. Plant layout and costing, if applicable
   g. Future scope
   h. References

Students should submit a neatly typed and hard bound Project Report at the end of the term in the format provided by the Department.

Every student will be examined orally based on the topic of his/her project and relevant area to evaluate 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. Term work assessment will be based on student's workup, performance and progress during the term.

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

Term Work Assessment:

The evaluation of students should be based on submitted project report, understanding of the project problem and the work carried out during semester.

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