JSS MAHAVIDYAPEETHA

JSS Science and Technology University

(Formerly SJCE),

JSS Technical Institutions Campus, Mysuru-06

Scheme of Teaching and Examination for

M. Tech., in Polymer Science and Technology

Applicable for students admitted in 2017

(I to IV semester Approved in BOS Meeting 2017)

CREDIT DETAILS

SEMESTER I	**28 credits**
SEMESTER II	**28 credits**
SEMESTER III	**18 credits**
SEMESTER IV	**26 credits**
Total	**100 Credits**

JSS MAHAVIDYAPEETA
JSS Science and Technology University
(Formerly SJCE), Mysuru – 570 006

DEPARTMENT OF POLYMER SCIENCE AND TECHNOLOGY
SCHEME OF TEACHING

I Semester M. Tech. – Polymer Science & Technology
Applicable for students admitting in 2017

Subject code	Name of the subject	Teaching Department	Credits				Contact hours	Marks			Exam duration in hrs
			L	T	P	Total		CIE	SEE	Total	
PST110	Polymer Chemistry	PST	5	0	0	5	5	50	50	100	03
PST120	Polymer Characterization	PST	5	0	0	5	5	50	50	100	03
PST130	Polymer Physics and Rheology	PST	5	0	0	5	5	50	50	100	03
PST14X	Elective 1	PST	5	0	0	5	5	50	50	100	03
PST15X	Elective 2	PST				5	5	50	50	100	03
PST16L	Polymer Synthesis and Characterization Lab	PST	-	-	1.5	1.5	3	50	-	50	-
PST17S	Seminar	-	-	-	1.5	1.5	-	50	-	50	-
			Total Credits			**28**		**Total Marks**		**600**	

L=Lecture, T= Tutorial, P=Practical

Elective subjects:

Elective 1		Elective 2	
Subject code	**Course title**	**Subject code**	**Course title**
PST141	Surface Coating and Adhesion Technology	PST151	High Performance Polymers
PST142	Latex and Foam Technology	PST152	Applied Mathematics
PST143	Polymer Reaction Engineering	PST153	Research Methodology
PST144	Engineering Design With Rubber	PST154	Statistical Quality Control

JSS MAHAVIDYAPEETA
JSS Science and Technology University
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Department of Polymer Science and Technology

SCHEME OF TEACHING

II Semester M. Tech., – Polymer Science & Technology
Applicable for students admitting in 2017

Subject code	Name of the subject	Teaching Department	Credits				Contact hours	Marks			Exam duration in hrs
			L	T	P	Total		CIE	SEE	Total	
PST210	Polymer Processing	PST	5	0	0	5	5	50	50	100	03
PST220	Designing of Novel Polymeric Materials	PST	5	0	0	5	5	50	50	100	03
PST230	Polymer Structure Property Relationships	PST	5	0	0	5	5	50	50	100	03
PST24X	Elective 3	PST	5	0	0	5	5	50	50	100	03
PST25X	Elective 4	PST	5	0	0	5	5	50	50	100	03
PST26L	Polymer Processing and Testing Lab	PST	-	-	1.5	1.5	3	50	-	50	-
PST27S	Seminar	-	-	-	1.5	1.5	-	50	-	50	-
			Total Credits			**28**		**Total Marks**		**600**	

L=Lecture, T= Tutorial, P=Practical

Elective subjects:

Elective 3		Elective 4	
Subject code	**Course title**	**Subject code**	**Course title**
PST241	Polymer Degradation and Stabilization	PST251	Fiber Technology
PST242	Polymer Product and Mould Design	PST252	Advanced Rubber Technology
PST243	Design of Advanced Polymer Composites	PST253	Polymer Membranes and Drug Delivery
PST244	Fabrication of Intrinsic Conducting Polymers	PST254	Specialty and Functional Materials
		PST255	Nano structured Materials

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Department of Polymer Science and Technology

SCHEME OF TEACHING

III Semester M. Tech., – Polymer Science & Technology
Applicable for students admitting in 2017

Sl. No	Subject code	Course title	Teaching department	Credits				Contact hours	Marks			Exam duration in hrs
				L	T	P	Total		CIE	SEE	Total	
1.	PST31T	Practical Training in Industry / Exploration Research	-	0	0	4	4	–	100	–	100	–
2.	PST32P	Project Work (Phase-I)	-	0	0	14	14	–	100	–	100	–
				Total credits			**18**	**–**	**Total marks**		**200**	–

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Department of Polymer Science and Technology

SCHEME OF TEACHING

IV Semester M. Tech., – Polymer Science & Technology
Applicable for students admitting in 2017

Sl. No	Subject code	Course title	Teaching department	Credits				Contact hours	Marks			Exam duration in hrs
				L	T	P	Total		CIE	SEE	Total	
1	PST41P	Project Work (Phase-II)	-	–	–	26	26	–	100	200	300	3
				Total credits			**26**	**–**	**Total marks**		**300**	**–**

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Department of Polymer Science And Technology

Scheme of Evaluation for III & IV Semesters of M.Tech., Programme

Event	Normal Period	Credits	Expected Outcome	Remarks
III Semester				
Industrial Training	September 2nd Week	04	Report on industrial training / presentation	25% weightage for external evaluation 75% weightage for internal evaluation
CIE-I Synopsis Evaluation	October 1st Week	04	Synopsis presentation with Objectives / Scope / Literature Survey	By department committee
CIE-II Midterm Evaluation-I	December 1st Week	06	Comprehensive review of the progress	By department committee
CIE-III Verification of compliance	January 2nd Week	04	Verification of Compliance of midterm evaluation-I	By department committee
IV Semester				
CIE-IV Midterm Evaluation-II	April 2nd Week	08	Comprehensive review of the progress	By department committee
CIE-V Final Internal Seminar / Demonstration	June 2nd Week	08	Discussion with final results and conclusions	By department committee
Report Preparation and Submission	July 2nd Week	–	–	–
Thesis Evaluation and Viva-Voce	On or before 30th August	10	–	By the panel of examiners with HOD or his nominee as Chairman
Results	31st August	–	–	–

Note: 1. Marks awarded for Industrial Training and total marks awarded for CIE-I, CIE-II and CIE-III put together shall be sent to the controller of examination by the 3rd week of January.

2. Marks awarded for CIE-IV and CIE-V put together shall be sent to the controller of examination by the end of June.

Schedule of Events during the 2nd Year of M.Tech. Programme

- **Commencement of III Semester** : 13th July
    - Industrial Training (8 weeks) : 13th July – 5th September
    - Evaluation of Industrial Training : 2nd Week of September
- Reporting to Project work : 7th September
    - **CIE-I:** Evaluation of Synopsis : 1st Week of October
    - **CIE-II:** Mid-term Evaluation-I : 1st Week of December
    - **CIE-III:** Verification of Compliance of Mid-term Evaluation-I : 2nd Week of January
- **Commencement of IV Semester** : 16th January
    - **CIE-IV:** Mid-term Evaluation-II : 2nd Week of April
    - **CIE-V:** Final Internal Seminar / Demonstration of the Project Work : 2nd Week of June
    - Preparation of the M. Tech. Dissertation : 3rd Week of June-2nd Week of July
    - Submission of the M. Tech. Dissertation : 2nd Week of July
    - Viva-Voce : On or before 30th August
- **Announcement of the Results** : 31st August

Note: 1. If any day indicated is a holiday, then the event shall happen the next working day.

2. Marks awarded for Industrial Training and total marks awarded for CIE-I, CIE-II and CIE-III put together shall be sent to the controller of examination by the 3rd week of January.

3. Marks awarded for CIE-IV and CIE-V put together shall be sent to the controller of examination by the end of June.

PST110: POLYMER CHEMISTRY (5:0:0)		
Contact Hours: 5/week		
Course Outcomes: Upon successful completion of this course, the students will be able to		
CO1	Explain the basic concepts of functionality, monomer, polymer and classifications.	
CO2	Explain the methods of polymerizations and factors affecting on polymerization reactions	
CO3	Explain the different polymerization methods	
CO4	Explain the special topics in polymer synthesis and modification of polymers via chemical reactions for tailor made applications.	
CO5	Explain the ring opening polymerizations and purification of polymers	
Course Content:		
Unit 1	**General introduction** Introduction to polymers with emphasis on important concepts such as monomer, functionality and physical state (amorphous and crystalline), classification of polymers on the basis of source, elemental composition, heat, pressure, chemical reactivity, chemical/monomer composition, geometry and stereo regularity. Molecular weight of polymers – types of average molecular weight, molecular weight distribution (MWD) and its practical significance, experimental methods to determine molecular weight.	**10h**
Unit 2	**Chemistry and Mechanism of Polymerization** Definition of polymerization, factors affecting polymerization, mechanism of chain (addition) polymerization (free radical, ionic and co-ordination (stereo regular) polymerizations), Zeigler-Natta catalyst Mechanism of step (condensation) polymerization (with examples- Nylon 66, polyethylene terephthalate (PET) and phenol-formaldehyde (PF)) - molecular weight in step growth polymerization, kinetics of step growth polymerization	**10h**
Unit 3	**Methods of Polymerization** Bulk, solution, precipitation, suspension, emulsion polymerization, solid phase, gas phase and (formulations, mechanism, properties of the polymer produced, advantages and disadvantages of each technique). Polyaddition polymerization, melt polycondensation, interfacial polymerization, solution polycondensation (advantages and disadvantages of each technique).	**10h**

Unit 4	**Copolymerization** – introduction, free radical, ionic and copoly-condensation (with examples). **Special topics in polymer synthesis-** Electrochemical polymerization, metathesis polymerization, group-transfer polymerization, ATRP, plasma polymerization. Advanced polymerization techniques. **Reactions of synthetic polymers -** Chemical modification; preparation of polymer derivatives.	**10h**
Unit 5	**Ring Opening polymerizations** General characteristics and polymerizability of cyclic monomers, ring opening polymerization of cyclic ethers, anionic polymerization of epoxides, cationic polymerization of cyclic amides (lactams), cyclic polymerizations of lactones and some aspects of biodegradable ring opening polymers: glycolides & lactides. **Isolation and purification of polymers-** polymer fractionation-fractional precipitation technique partial dissolution (extraction) technique.	**10h**

References:

1. R. J. Young and P. A. Lovell, Introduction to Polymers., 3rd edition, CRC Press, New York, 2011.
2. Gowariker, V. R.; Viswanathan, N. V., Polymer Science**;** Wiley: New York, 1986.
3. Billmeyer Fred W. JR., Text book of polymer science, Wiley & Sons, New York, 1984.
4. Rodriguez, F., Principles of Polymer Systems. 2nd Edition, McGraw-Hill Companies, New York, U.S.A., 1982.
5. Raymond B. Seymour and Charles E. Carraher, Jr., Marcel Dekker AG, Polymer chemistry: An introduction. New York, 1981.
6. Odian G, Principles of Polymerization. 4th edition, Wiley Inter Science, New York, 2004.
7. Anil Kumar and Rakesh Gupta, Fundamentals of Polymer Engineering, Marcel Dekker, New York, 2003.
8. G.S. Mishra, Introductory polymer chemistry, New Age International, 1993

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PST120: POLYMER CHARACTERIZATION (5:0:0)		
Contact Hours: 5/week		
Course Outcomes: Upon successful completion of this course, the students will be able to		
CO1	Explain the different spectroscopic techniques	
CO2	Explain the principle and applications of thermo-analytical techniques	
CO3	Describe the Microscopic, X-ray and chromatographic techniques	
Course Content:		
Unit 1	**Introduction to analytical instrumentation** - Calibration, accuracy, precision, reproducibility, standard deviation. **Spectroscopic Methods** Introduction, classification**,** Ultra-violet/Visible spectroscopy - Introduction, principle, Lambert law, Beer's law, theory, instrumentation, procedure, advantages, disadvantages, interpretation of spectrogram, applications-qualitative analysis, quantitative analysis; purity, cis- and trans- conformation. Numerical	**10h**
Unit 2	**Fourier transform infrared (FTIR) spectroscopy** Introduction, principle, theory, instrumentation, procedure, methods of sample preparation, advantages, disadvantages, interpretation of spectrogram, and applications-establishment of chemical structure of polymers, reaction kinetics, polymer linkage, hydrogen bond formation, purity, copolymerization, qualitative and quantitative results. **Chromatographic techniques** Principle of Gel permeation chromatography (GPC), mechanism of separation, theory/techniques, instrumentation, molecular weight determination and distribution (MWD), purity, composition, other applications.	**10h**
Unit 3	**Nuclear Magnetic spectroscopy (NMR)- (^{1}H NMR and ^{13}C NMR)** Introduction Principle, theory, Spin-spin coupling, coupling constant, instrumentation, procedure, method of sample preparation, advantages, disadvantages, applications – chemical structures, purity, tacticity.	**10h**
Unit 4	**Thermal Methods** Introduction, general classification, advantages of the TA methods; Differential scanning calorimetry (DSC and MDSC)- Introduction, theory, instrumentation,	**10h**

	method of analysis, factors affecting on DSC results, advantage, disadvantage, interpretation of DSC thermograms, applications - T_g, T_m, determination of blends composition, purity, identification of unknown polymers, degree of crystallization, degree of cure and rate of cure studies/kinetics of curing, plasticizers effect, Thermo gravimetric analysis (TGA) - Introduction Principle, theory, instrumentation, procedure for analysis of sample, factors influence on studies, advantages, disadvantages, applications – Purity, fiber content, composition of compounded rubbers, identification of polymers/rubbers, thermal stability, thermal degradation, kinetics of thermal degradation and IPDT. Dynamic mechanical Analysis (DMA)- Introduction, principle, instrumentation, and its applications.	
Unit 5	**Microstructural analysis** X-ray diffractometry: X-ray diffraction analysis, experimental methods, applications-Chain conformations, chain packing, disorder in the crystal, degree of crystallinity, micro structural parameters, degree of orientations Microscopic analysis: SEM, TEM, AFM; Morphology of polymers, Crystallization behavior, phase separation and other applications.	**10h**

References:

1. D.Campbell and J.R. White – Polymer Characterization – Physical Techniques (Chapman and Hall), 1989
2. F.W.Billmeyer-Text book of Polymer Science - 3^{rd} ed. Wiley Interscience,1984.
3. K.J.Saunders-The Identification of Plastics and Rubber , Chapman & Hall, London 1970.
4. William C. Wake -Analysis of Rubber and Rubber like Polymers – Rev. ed. Wiley Interscience, New York 1969.
5. E.Turi -Thermal Characterization of Polymeric materials -Academic Press,New York 1981.

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PST130: POLYMER PHYSICS AND RHEOLOGY(5:0:0)
Contact Hours: 5/week
Course Outcomes: Upon successful completion of this course, the students will be able to

CO1	Explain fundamentals of polymer physics and explain chain conformations in polymers.		
CO2	Explain polymer solution behavior and factors affecting the crystallizability.		
CO3	Explain crystalline morphology and kinetics of crystallization.		
CO4	Explain a suitable rheological model for a given application.		
CO5	Explain linear viscoelasticity and the importance of rheology in polymer processing.		
Course Content:			
Unit 1	**Introduction** Fundamental definitions, configurational states, shapes of polymer molecules-bonding, conformation and chain statitiscs, typical bond lengths and angles, molar mass and repeating units. **Chain conformations in polymers** Introduction, conformations (eclipsed, staggered, stable-trans and gauche, conformational energy of ethane and n-butane), a single ideal chain mean-square end-to-end distance, radius of gyration, Gaussian chain. Freely jointed chain. Models for calculating the average end-end distance: freely jointed chain, freely rotating chain, hindered rotation, realistic chain-excluded volume method, random flight analysis, Worm-like chain, chains with preferred confirmations and numericals.	**10h**	
Unit 2	**Polymer solutions** Flory-Huggins Theory, osmotic pressure, The glass transition; free volume theory, factors affecting the T_g. Crystallization and melting and glass transition temperature; Degree of crystallization, factors affecting the crystallizability, Measurements of crystallinity, T_g - Definition, Factors influencing the glass transition temperature, T_g and Molecular weight, T_g, effect of plasticizers, T_g and co-polymers, T_g and T_m, Importance of T_g, Numerical problems on these topics.	**10h**	
Unit 3	**Crystalline Morphology** Introduction, degree of crystallinity, experimental determination, crystallites-fringed micelle model, chain folded crystallites, extended chain crytallites, spherulites and other polycrystalline structures, theories of chain folding and lamellar thickness. Crystallinity in Polymers - Morphology of Crystalline Polymers- Lamellae, Folded chain model, Spherulites, The fringed micelle model,	**10h**	

	mechanism of Spherulites formation, crystallization and melting. Kinetics of crystallization: Theories of crystallization kinetics, Avrami equation. Numericals.	
Unit 4	**Polymer rheology** Introduction to rheology, fundamental concepts of creep and stress relaxation. Boltzmann superposition principle, Rheological models - Maxwell, Kelvin, Voight, Standard linear model. Response of elastic, viscous and viscoelastic materials for static and cyclic load, complex modulus and compliance, numericals.	**10h**
Unit 5	**Linear viscoelasticity** Introduction to linear viscoelasticity, real materials-relaxation and retardation time spectra. Master curve and time-temperature super position, analysis of time-temperature scans, frequency scans. **Applications of rheology in polymer processing** Importance of rheology in polymer processing, time dependence of viscous flow, rheology of injection molding and blow molding. Flow in capillaries, slits and dies, numericals.	**10h**

References:

1. Ulf W. Gedde. Polymer physics. First edition, Kluwer academic publishers, 1999.
2. B. R. Gupta. Applied Rheology in Polymer Processing. Asian Books Private Limited, New Delhi, 2005.
3. E. T. Severs. Rheology of Polymers. Reinhold Publishing Co., New York, 1962.
4. D. I. Bower**.** An Introduction to Polymer Physics**.** Cambridge University Press, 2002
5. J. A. Brydson. Flow Properties of Polymer melts. 2nd edition, Ilife Books, London, 1981.
6. C. D. Han. Rheology in Polymer Processing, Academic Press, New York, 1976.
7. J. M. Dealy & Wissbrun. Melt Rheology & its role in Plastics Processing. Kluwer, 1990.

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PST141: SURFACE COATING AND ADHESION TECHNOLOGY (5:0:0)	
Contact Hours: 5/week	
Course Outcomes: Upon successful completion of this course, the students will be able to:	
CO1	Explain the synthesis, properties, applications of surface coating resins, pigments and

	pigment dispersions	
CO2	Describe different surface preparation methods and coating processes.	
CO3	Explain evaluation methods and applications of surface coatings	
CO4	Discuss the fundamental aspects and classification of adhesives	
CO5	Describe different test methods and application of adhesives	
Course Content:		
Unit 1	**Industrial coating resins** Synthesis, properties, formulations and applications as coatings of the following resins to be discussed. Alkyds and polyesters, phenol formaldehyde, silicon resin, epoxy resin, chlorinated rubber, polyurethanes and acrylic resins. **Pigments & dispersion** Manufacturing and properties of organic and inorganic pigments. Factors affecting dispersions, preparation of pigment dispersion, grinding equipment.	**10h**
Unit 2	**Coating processes -** Surface preparation: mechanical cleaning, solvent cleaning, alkali cleaning and acid pickling. Chemical conversion treatment. **Coating application**: mechanism of film formation **Applying processes**: brushing, dip coating and flow coating, curtain coating, roller coating and spray coating Fixation **Curing**: Physical, chemical and oxidative; Factors affecting coating properties.	**10h**
Unit 3	**Testing and evaluation of coatings** Physico-mechanical, optical, and environmental properties. **Application of surface coating -** Appliance finishes, automotive finishes, coil coating, can coating, marine coating and aircraft coating, Powder coating	**10h**
Unit 4	**Fundamental aspects of adhesion technology** Theories and mechanism of adhesion, types of adhesions **Adhesive classes** Structural adhesives: Epoxies, PF, UF and MF Non structural adhesives: Natural rubber (NR), poly ester based (unsaturated polyester), silicone, acrylics (reactive, aerobic, anaerobic and cyano acrylics), polyurethane, poly vinyl acetate and ethylene vinyl acetate copolymer.	**10h**

Unit 5	**Testing of adhesives -** Adhesive joint strength, environmental and related considerations, fracture mechanics **Application of adhesives -** Adhesives in electronics, wood and automotive industry, Dentistry and drug delivery	**10h**

References:

1. Swaraj Paul, Surface coatings; Science and Technology,2nd edition, John Wiley & Sons, Inc. 1995.
2. Pizzi, A. (ed); Mittal, K.L. (ed), Hand book of Adhesive technology, Marcel Dekker, New York, 1996.
3. Edward M Petrie, Hanbook of Adhesives & Sealants, Mc Grew-Hill, Newyork , 2000
4. R Lambourne and T R Strivens, Paint & Surface coatings. Theory and practice, 2nd edition, Woodhead Publishing Limited, 1999.
5. Charles A. Harper: Handbook of Plastics, Elastomers, and Composites, Fourth Edition. Plastics in Coatings and Finishes, McGraw-Hill Professional, AccessEngineering, 2002.
6. Lucas F. M. da Silva, Andreas Ochsner, Robert D. Adams, Handbook of Adhesion Technology, Springer- verlag Berlin Heidelberg 2011.
7. Cagle, Charles V, Handbook of adhesive bonding, Mc Graw` Hill.1982.
8. J. Sheilds, Adhesives Hand Book, 3rd edition, Butterworths, 1985.
9. R.Houwink and G.Solomon, Adhesion and Adhesives, Amsterdam Elsevier, 1965-1967.
10. Skeist, irving, Handbook of adhesives, 2nd edition, Van Nostrand Reinhold Co., 1977.

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PST142: LATEX AND FOAM TECHNOLOGY (5:0:0)	
Contact Hours: 5/week	
Course Outcomes: Upon successful completion of this course, the students will be able to	
CO1	Explain the basics of natural and synthetic lattices
CO2	Describe the importance of various compounding ingredients and specifications of latex
CO3	Explain the concepts of latex product manufacturing
CO4	Explain latex foam process and characterization methods.
CO5	Discuss the chemistry, structure-property and foam process of rigid and flexible polyurethane foams

Course Content:		
Unit 1	**Introduction** Terminologies, classification of latex, properties and application of latex, handling of latex. **NR and Synthetic lattices -** Methods of manufacture, properties and applications of Natural rubber latex, Synthetic lattices like, SBR, XSBR, HSBR, vinyl pyridine latex, NBR, XNBR, PCR, PVAc, PVC and acrylic latex. Artificial lattices.	**10h**
Unit 2	**Compounding of latex -** Vulcanizing ingredients, stabilizers, destabilizing agents and heat sensitizing agents, micro and nano fillers, protective agents, dispersing agents, thickeners. Preparation of aqueous solutions, dispersions and emulsions. **Testing of latex** - Total solid content, DRC, mechanical stability, chemical stability, pH, KOH number, VFA number, particle size and size distribution of dispersion.	**10h**
Unit 3	**Manufacture of latex based products -** Latex thread, Dipped goods, Carpet backing, casting, spraying, spreading, rubberized coir, rubberized hair, Micro-porous Ebonite, Can sealing, Latex cements, Latex laminated paper and boards, Latex coated fabrics and cords, adhesives, emulsion paints, and electro deposition of latex.	**10h**
Unit 4	**Latex foam -** Preparation of compound, gelation, foaming, molding, curing, finishing, Dunlop and Talalay process. Application of latex foam. Foam testing: Density, hardness, Flexing, static compression set, elongation at break, ageing, and low temperature flexibility. **Microcellular foams -** Introduction, processing of microcellular foams (solid state batch process, semi continuous process, extrusion methods), concepts of open and closed cell structure, properties and applications.	**10h**
Unit 5	**Rigid and flexible polyurethane foam -** Raw materials, blowing agents (chemical and physical blowing agents, selection criteria), chemistry, manufacturing process, properties and applications. Nanofoams	**10h**

References:

1. K.O.Calvert. Polymer lattices and their applications, Macmillan publishing Co., NY, 1982
2. D.C.Blackley. Polymer lattices; Science and Tech., Vol 1, 2 and 3. Chapman & Hall., 1997.
3. E.W. Madge. Latex Foam Rubber, MacLaren and Sons Ltd., London, 1962.
4. David Eaves. Handbook of polymer foams. RAPRA Technology, UK, 2004.
5. Gunter Oertel. Polyurethane hand book, Hanser Publisher, NY, 1994.

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PST143: POLYMER REACTION ENGINEERING (5:0:0)		
Contact Hours: 5/week		
Course Outcomes: Upon successful completion of this course, the students will be able to		
CO1	Explain the kinetics and mechanisms of Free-Radical Polymerization - Homogeneous Systems	
CO2	Explain Heat removal and temperature programming of Homogeneous Free-Radical Polymerization reactions taking place Batch , Semibatch, CSTR and tubular	
CO3	Explain Modeling of Free-Radical Polymerization (Heterogeneous) taking example of HIPS polymerization	
CO4	Explain Control of Polymerization Reactors	
Course Content:		
Unit 1	Free-Radical Polymerization - Homogeneous Systems Introduction to Polymerization reactors - FRP mechanisms and kinetics.	**10h**
Unit 2	Free-Radical Polymerization - Homogeneous Systems - Heat removal and temperature programming - Batch reactors - Semibatch (semicontinuous) reactors - Continuous stirred-tank reactors - Tubular reactors. Gas phase reactor system	**10h**
Unit 3	Free-Radical Polymerization: Heterogeneous Systems – case study of High-impact polystyrene - Modeling HIPS polymerization.	**10h**
Unit 4	Control of Polymerization Reactors - Characterization of the control problem - Classical polymerization reaction control problems- Control of reaction rates and of reactor temperature.	**10h**
Unit 5	Control of Polymerization Reactors - Control of monomer conversion and polymer	**10h**

	production - Control of molecular weight averages and MWDs - Control of copolymer composition - Control of particle size and PSDs.	

References:

1. José M. Asua ,Polymer Reaction Engineering , , Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK, 2007
2. Nauman, E. B.,Chemical Reactor Design, Optimization and Scale up, Mc-Graw Hill, New York, 2002.
3. Thierry Meyer (Editor), Jos Keurentjes (Editor), Handbook of Polymer reaction Engineering, ISBN: 3-527-31014-2, Wiley VCH, Weinheim, 2005.
4. Nauman, E. B., Chemical Reactor Design, Wiley, New York, 1987.

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PST144: ENGINEERING DESIGN WITH RUBBER (5:0:0)

Contact Hours: 5/week

Course Outcomes: Upon successful completion of this course, the students will be able to

CO1	Explain the unique properties of rubbers
CO2	Explain rubber behavior with respect to static and dynamic loads in designing.
CO3	Design molds and dies for rubber products.
CO4	Design rubber products for damping, packaging and sealing applications.
CO5	Explain the dynamic behavior of rubber/compounds through experimental technique(s).

Course Content:

Unit 1	**Introduction to the static load-deformation** **Properties of rubber** **Large strain theory**: Theory of rubber elasticity, kinetic & phenomenological theory.	**10h**
Unit 2	**Dynamic force-deformation properties**: Linear & non-linear viscoelastic behavior. **Theories of strength:** Influence of hysteresis on strength, strength and fracture processes. Dynamic mechanical analysis of rubber	**10h**

	Deformation of rubber units under equilibrium loading condition. Deformation of rubber units in shear compression & torsion.	
Unit 3	**Damping**: Dynamic spring stiffness, spring curve, Rubber springs. Basic concept of various rubber mountings and their design criteria. Vibration isolation & transmissibility-single degree of freedom system-isolation of shock & transient vibration-simple linear system. **Introduction to the mold and die design**, factors to be considered for mold & die design. Design procedure for different molds.	**10h**
Unit 4	**Rubber in packaging,** theory of bulk cushioning material-solid runner mats, design aspect. **Bridge bearing** – classification – design and principle	**10h**
Unit 5	Rubber in fluid sealing static & dynamic sealing – design characteristics. Flexible composite – Diaphragms & their analysis, air spring and their analysis.	**10h**

References:

1. A.N. Gent, Engineering with Rubber: How to design rubber components, Carl Hanser Verlag, Munich,1992.
2. Crawford, R. J. Plastics engineering; 3rd ed.; Butterworth-Heinemann: Amsterdam, 1998.
3. McCrum, N. G.; Buckley, C. P. Principles of polymer engineering; Oxford University Press: Oxford, 1988.
4. B. R. Gupta, Applied Rheology in Polymer Processing, Asian Books Private Limited, New Delhi, 2005.
5. Treloar, L. R. G. The physics of rubber elasticity; 3rd ed.; Clarendon Press ; Oxford, 2005
6. E.F.Gobel, Rubber spring design, ISBN-13:9780470308554,Wiley. John & Sons,1974

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PST151: High Performance Polymers (5:0:0)	
Contact Hours: 5/week	
Course Outcomes: Upon successful completion of this course, the students will be able to	
CO1	Explain the synthesis, structure-property relationships and applications of engineering polymers
CO2	Explain miscibility of blends and select the polymers for high-performance applications
CO3	Discuss the performance of polymers as bio-materials, LCPs & membranes.

Course Content:		
Unit 1	Manufacturing (in brief), process-ability, structure-property relationships and the end use (applications) are to be discussed for the following engineering/ highperformance polymers with case studies: Polyamides, PET, PBT, PTFE, PC, PCTFE, PVDF, Polyarylate, Polyaramid, Polyimides, Polyamide imides, Polyphenelene Sulphide, Polysulphone.	**10h**
Unit 2	Manufacturing (in brief), process-ability, structure-property relationships and the end use (applications) are to be discussed for the following engineering/ high performance polymers with case studies: Polyacetals, Poly phenylene oxide (PPO), Polyphenylene ether (PPE), Polyketones (PEK, PEEK), Ultra High Molecular Weight Poly Ethylene, Acrylonitrile butadiene styrene.	**10h**
Unit 3	**Polymer Blends:** Fundamentals of polymer blends and alloys, Designing a polymer blend, Mixers, Thermodynamic aspects of blending, Factors affecting miscibility of polymer blends- Thermodynamics, compatibility, solubility parameter, interaction parameter, composition, molecular weight, transition temperature, mechanism of blending, etc. Properties of miscible and immiscible blends. Morphology and Phase behaviours.	**10h**
Unit 4	**Designing of Blends:** Compatibilization (Alloying) Methods- types and role of compatibilizer, compatibilization methods, IPNs, mechanism and properties of compatibilized blends. Degree of compatibilization. Mechanism and theory of toughening, Toughening of thermoplastics and thermosets; Thermoplastic elastomers (TPEs). Blends of engineering polymers- based on PC, Polyamides, Polyesters [Case study including properties and applications].	**10h**
Unit 5	**Biomaterials, Liquid Crystalline Polymers, Membranes** Biomaterials: polymeric implant materials (Polyolefins, polyamides, acrylic polymers, fluorocarbon polymers, silicon rubbers, acetals). Biodegradable polymers for medical purposes, Biopolymers in controlled release systems. Biocompatibility & toxicological screening of biomaterials. Polymeric Membranes: Synthetic polymeric membranes and their applications. Liquid Crystalline Polymers: Requirements, classification, examples, properties, applications.	**10h**

References:

1. Michael L Berins. Plastic Engineering handbook of the society of plastics industry Inc, 5^{th} Ed, Van Nostrand Reinhold, 1991.
2. Jacqueline I Kroschwitz. Concise Encyclopedia of Polymer Science and Engineering, Wiley, 1990.
3. James M Margolis. Engineering Thermoplastics properties and application, Marcel Dekker

Inc, New York, 1985.
4. Paul and Newman. Polymer blends, Academic press, NewYork, 1978.
5. Lloyd M Robeson. Polymer blends– A comprehensive review, Hanser publishers, 2007.
6. John Mason and Leslie H Sperling. Polymer blends and composites, Plenum Press, New York, 1976.
7. J B Park, Biomaterials - Science and Engineering, Plenum Press, 1984.
8. Sujata V. Bhat, Biomaterials, Narosa Publishing House, 2002.
9. Jonathan Black, Biological Performance of materials, Marcel Decker, 1981
10. C.P.Sharma & M.Szycher, Blood compatible materials and devices, Technomic Publishing Co. Ltd., 1991
11. Piskin and A.S. Hoffmann, Polymeric Biomaterials (Eds), Martinus Nijhoff Publishers. (Dordrecht. 1986)
12. Eugene D. Goldbera , Biomedical Polymers, Akio Nakajima
13. A . Rembaum & M. Shen, Biomedical Polymers, Mercer Dekkar Inc. 1971
14. L. Hench & E. C. Ethridge, Biomaterials - An Interfacial approach

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PST152: APPLIED MATHEMATICS (5:0:0)		
Contact Hours: 5/week		
Course Outcomes: Upon successful completion of this course, the students will be able to		
CO 1	Explain ODEs/PDEs and apply suitable numerical methods to solve them.	
CO 2	Solve systems of linear equations by exact / approximate methods, determine eigenvalues.	
CO 3	Recognize suitable techniques to handle the given data and adopt correct method for curve fitting.	
CO 4	Determine values of functions by applying proper algorithms.	
CO 5	Interpret large data and compute measures of central tendency and deviations from measures of central tendency.	
Course Content:		
Unit 1	**Ordinary and Partial differential equations:** basic definitions and classification; examples from physical world–mass-spring system ODE, heat equation, wave equation and diffusion equation. **Systems of linear equations and matrix computations:** basic terminolgy – consistency, overdetermined systems; exact and approximate solutions of systems	**10h**

	of linear equations – Gauss / Gauss-Jordan elimination, LU-factorisation, Gauss / Gauss-Seidel iterative method; eigenvalues/eigenvectors– characteristics equation, power method of determining the dominant eigenvalue; inverses of square matrices.	
Unit 2	**Curve fitting:** Polynomial interpolation – Newton difference formulas, Lagrange interpolation, Bezier curves; least square fitting lines / quadratic curves. **Root finding:** Method of bisection, Chord method, Newton-Raphson's method and combinations of these methods; **Statistics:** measures of central tendencies, measures of deviations from central tendencies; correlation; basic sampling theory.	**10h**
Unit 3	Introduction to machine computation: Number representaion on a machine – min / max representable numbers, machine epsilon; errors arising out of approximations and propagation of errors – absolute / relative errors, error propagation during addition / multiplication of numbers, catastrophic addition;	**10h**
Unit 4 and Unit 5	Computational Softwares: Numerical packages (Matlab/Scilab/ Bench Calculator), symbolic Algebra packages (Maple/Mathematica) and statistical packages (Data Melt/R / SciPy). The practical will consists of using some of the above softwares to solve problems from the topics dealt with in the first part of the course.	**20h**

Reference:

1. R J Schilling, and S L Harris. Applied numerical methods for Engineers using MATLAB, 1st edition, Brooks/Cole Publishing Co.USA, 1999.

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PST153: RESEARCH METHODOLOGY (5:0:0)

Course Outcomes: Upon successful completion of this course, the students will be able to-

Contact Hours: 5/week

CO1	Explain the need of scientific research; and Conduct literature survey;
CO2	Critically evaluate current research and propose possible alternate directions for further work;

CO3	Develop hypothesis and methodology for research;	
CO4	Discuss basic statistics involved in data presentation, and to test the significance, validity and reliability of the research results;	
CO5	Comprehend and deal with complex research issues in order to communicate their scientific results clearly for peer review.	
Course Content:		
Unit 1	**Objectives and types of research:** Motivation and objectives – Research methods vs Methodology. Types of research with examples – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical. Literature survey tools/ search engines (Thomson Innovation, Scifinder, web of science).	**10h**
Unit 2	**Research Formulation:** Defining and formulating the research problem - Selecting the problem - Necessity of defining the problem - Importance of literature review in defining a problem – Literature review – Primary and secondary sources – reviews, treatise, monographs-patents – web as a source – searching the web - Critical literature review – Identifying gap areas from literature review - Development of working hypothesis.	**10h**
Unit 3	**Research design and methods:** Research design – Basic Principles- Need of research design –– Features of good design – Important concepts relating to research design – Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction, Development of Models. Developing a research plan - Exploration, Description, Diagnosis, and Experimentation. Determining experimental and sample designs.	**10h**
Unit 4	**Data Collection and analysis:** Execution of the research - Observation and Collection of data - Methods of data collection – Sampling Methods- Data Processing and Analysis strategies - Data Analysis with Statistical Packages - Hypothesis-testing - Generalization and Interpretation.	**10h**
Unit 5	**Reporting and thesis writing:** Structure and components of scientific reports - Types of report – Technical reports and thesis – Significance – Different steps in the preparation – Layout, structure and Language of typical reports – Illustrations and tables - Bibliography, referencing and footnotes - Oral presentation – Planning	**10h**

	– Preparation –Practice – Making presentation – Use of visual aids - Importance of effective communication. Application of results and ethics -– Reproduction of published material, Plagiarism - Citation and acknowledgement - Reproducibility and accountability. **Intellectual Property Rights:** IPRs- Invention and Creativity- Intellectual Property-Importance and Protection of Intellectual Property Rights (IPRs) - A brief summary of: Patents, Copyrights, Trademarks, Industrial Designs- Integrated Circuits-Geographical Indications-Establishment of WIPO-Application and Procedures.	

References:

1. Kothari, C.R., Research Methodology: Methods and Techniques, New Age International, 1990.
2. Garg, B.L., Karadia, R., and Agarwal, An introduction to Research Methodology, RBSA Publishers, U.K., 2002. Sinha, S.C. and Dhiman, A.K., Research Methodology, Ess Ess, 2002.
3. Trochim, W.M.K., Research Methods: the concise knowledge base, Atomic Dog Publishing, 2005.
4. Anthony, M., Graziano, A.M. and Raulin, M.L., Research Methods: A Process of Inquiry, Allyn and Bacon, 2009.
5. Day, R.A., How to Write and Publish a Scientific Paper, Cambridge University Press. 1992.
6. Fink, A., Conducting Research Literature Reviews: From the Internet to Paper. Sage Publications. 2009.
7. Coley, S.M. and Scheinberg, C. A., "Proposal Writing", Sage Publications, 1990.
8. Keith Eugene Maskus, Intellectual Property Rights in the Global Economy, Washington, DC, 2000.
9. Subbarau N R, Handbook on Intellectual Property Law and Practice- S. Viswanathan Printers and Publishing Private Limited, 1998.

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PST154: STATISTICAL QUALITY CONTROL (5:0:0)
Contact Hours: 5/week
Course Outcomes: Upon successful completion of this course, the students will be able to

CO1	Explain the philosophy and basic concepts of quality improvement and the DMAIC process	
CO2	Explain use of statistical process control methods	
CO3	Design, use and interpret control charts	
CO4	Explain the analysis of process capability and measurement system capability	
CO5	Explain Acceptance Sampling	
Course Content:		
Unit 1	**Quality Improvement in the Modern Business Environment and the DMAIC Process:** The Meaning of Quality and Quality Improvement, Dimensions of Quality ,Quality Engineering Terminology, A Brief History of Quality Control and Improvement, Statistical Methods for Quality Control and Improvement, Management Aspects of Quality Improvement, Quality Philosophy and Management Strategies, The Link Between Quality and Productivity, Quality Costs, Legal Aspects of Quality, Implementing Quality Improvement, The DMAIC Process, Examples of DMAIC.	**10h**
Unit 2	**Methods and Philosophy of Statistical Process and Control Charts for Variables:** Methods useful in quality control and improvement, modeling process quality, describing variation, the stem-and-leaf plot, the histogram, numerical summary of data, the box plot, probability distributions, important discrete distributions, the hypergeometric distribution, the binomial distribution , the poisson distribution, the pascal and related distributions, important continuous distributions, the normal distribution, the lognormal distribution, the exponential distribution, the gamma distribution,the weibull distribution, probability plots, normal probability plots, some useful approximations, comments on approximations.	**10h**
Unit 3	**Control Charts for Attributes:** Introduction, the Control Chart for Fraction Nonconforming, Development and Operation of the Control Chart, Variable Sample Size, Applications in Transactional and Service Businesses, The Operating-Characteristic, Function and Average Run Length, Calculations, Control Charts for Nonconformities (Defects), Procedures with Constant Sample Size, Procedures with Variable Sample Size, Demerit Systems, The Operating-	**10h**

	Characteristic Function, Dealing with Low Defect Levels, Nonmanufacturing Applications, Choice Between Attributes and Variables Control Charts, Guidelines for Implementing Control Charts.	
Unit 4	**Process and Measurement System Capability Analysis:** Introduction, Process Capability Analysis Using a Histogram or a Probability Plot, Using the Histogram, Probability Plotting, Process Capability Ratios, Use and Interpretation of Cp, Process Capability Ratio for an Off-Center Process, Normality and the Process Capability Ratio, More about Process Centering, Confidence Intervals and Tests on Process Capability Ratios, Process Capability Analysis Using a Control Chart, Process Capability Analysis Using Designed Experiments, Process Capability Analysis with Attribute Data, Gauge and Measurement System. Capability Studies. Attribute Gauge Capability, Setting Specification Limits on Discrete Components, Linear and Nonlinear Combinations, Estimating the Natural Tolerance Limits of a Process, Tolerance Limits Based on the Normal Distribution, Nonparametric Tolerance Limits.	**10h**
Unit 5	**Acceptance Sampling** Acceptance Control Charts, Control Charts for Multiple-Stream Processes, Group Control Charts, Other Approaches, SPC With Autocorrelated Process Data, Sources and Effects of Autocorrelation in Process Data, Model-Based Approaches, A Model-Free Approach, Adaptive Sampling Procedures, Economic Design of Control Charts, Designing a Control Chart, Process Characteristics, Cost Parameters. Advantages and Disadvantages of Sampling, Types of Sampling Plans, Lot Formation, Random Sampling, Guidelines for Using Acceptance Sampling, Single-Sampling Plans for Attributes, Definition of a Single-Sampling Plan, The OC Curve, Designing a Single-Sampling Plan with a Specified OC Curve, Rectifying Inspection, Double, Multiple and Sequential Sampling,	**10h**

References:

1. Douglas C. Montgomery, Introduction to Statistical Quality Control, 7th Edition, John Wiley & Sons, Inc, New York, 2013.
2. Douglas C. Montgomery, George C. Runger, and Norma F Hubele, Engineering Statistics,.
3. John Wiley & Sons, Inc., New York, 1999.
4. Douglas C. Montgomery and George C. Runger, Applied Statistics and Probability for Engineers, 5th Edition, John Wiley & Sons Inc., New York, 2010.

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PST16L: POLYMER SYNTHESIS AND CHARACTERIZATION LAB (0:0:1.5)	
Contact Hours: 3/week	
Course Outcomes: Upon successful completion of this course, the students will have an ability to-	
CO1	Explain the experimental procedure to synthesize & characterize the polymers along with its implications and to communicate it effectively;
CO2	Synthesize polymers and characterize them using modern tools;
CO3	Analyze, interpret and report the experimental data suitably.
List of experiments:	
1	Preparation of polyaniline– a conducting polymer.
2	Preparation of compatibilized polymer blend using Haake twin screw extruder.
3	Interfacial polymerization of polyamide or polyester.
4	Micro emulsion polymerization of methylacrylate.
5	Precipitation polymerization of acrylonitrile.
6	Redox polymerization for preparation of polyacrylamide.
7	Preparation of potassium or sodium methacrylate.
8	Determination of polymer-polymer miscibility by viscosity, refractive index, specific gravity measurement.
9	Qualitative analysis (identification) of polymers: Rubbers and Plastics.
10	Determination of dry rubber content and total solid content in rubber latex.
11	DSC Studies of polymer samples (T_g, T_m, T_{crys}, T_{deg}, T_{cure})

12	TGA studies of polymer samples (composition, ash content, thermal stability, degradation behavior).
13	DMA studies of polymer samples (T_g, modulus, phase behavior, Tan delta).
14	Chemical structure analysis of monomers, additives and polymers using FTIR.
15	Electrical properties: LCR meter.
16	Crystalline and phase studies: Polarizing Optical Microscope.
17	Viscosity average molecular weight.
18	Chemical resistance of polymers.
19	Determination of acid value and hydroxyl value.

References:

1. Practicals in Polymer Science - Synthesis and Qualitative & Quantitative Analysis of Macromolecules, Siddaramaiah, CBS publishers & distributors pvt ltd. New Delhi 2012.
2. A practical course in polymer chemistry – S.H. Pinner, 1961 Oxford.
3. H. Lee and K. Neville in Encyclopedia of polymer science and technology, Vol. 6 Interscience, New York (1967)
4. R.A.Coderre, in Encyclopedia of Chemical Technology, 1st Suppl. Vol., Interscience, New York (1957).
5. Experiments in polymer Science – Collins, Bares & Billmeyer, John Willey and Sons.
6. Annual Book of ASTM standards – ASTM publishers, Philadelphia – 1989.
7. Experimental Methods in Polymer Chemistry – Jan F. Rabek, John Wiley.
8. Macromolecular Synthesis Vol 1 to 5, - J.A. Moore Ed, John Wiley.

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PST210: POLYMER PROCESSING (5:0:0)	
Contact Hours: 5/week	
Course Outcomes: Upon successful completion of this course, the students will be able to-	
CO1	Explain the different polymer processing techniques.
CO2	Derive polymer melt constitutive equations from first principle
CO3	Explain the mix quality and the mixing mechanism.
CO4	Design and control the process steps/parameters of reactive processing.

CO5	Model and simulate the flow behavior of polymer melt mold filling.	
Course Content:		
Unit 1	**Introduction to polymer processing -** Current polymer processing practice, analysis of polymer processing in terms of elementary steps and shaping methods. Introduction to polymer processing techniques- principle, design, typical applications and case studies of extrusion, injection molding, thermoforming and film blowing.	**10h**
Unit 2	The balance equations and Newtonian fluid mechanics. Non-Newtonian Fluid mechanics, polymer melt constitutive equations.	**10h**
Unit 3	**Mixing -** Introduction, distributive and dispersive mixing, mix quality evaluation, residence time and strain distributions. Mixing equipments, mixing mechanisms, extruder as a mixer, motionless mixers, mixing in a stirred tank and practical aspects of mixing.	**10h**
Unit 4	**Reactive Polymer processing and compounding -** Classes of polymer chain modification reactions carried out in reactive polymer processing equipment, strategy of reactive extrusion. Reactor classifications, reactive compatibilization, grafting techniques, functionalization of end groups, compatibilization by additives, Polymer compounding.	**10h**
Unit 5	**Injection molding -** Introduction, feed system, hot and cold runners, balanced runner system, flow in an idealized runner system, theoretical aspects of mold filling and simulation, molding window diagram, practical aspects of injection molding, applications and trouble shooting	**10h**

References:

1. Zehev Tadmor and Costa G. Gogos, Principles of polymer processing, 2nd edition, Jhon wiley and Sons Inc. Publication, New Jersey, 2006.
2. Charles A Harper, Handbook of Plastic Processes, Jhon wiley and sons Inc. Publication, Newjersey, 2006.
3. Donald G. Baird and Dimitris I. Collias, Polymer processing, principles and design, John Wiley and Sons Inc., NY, 2001.
4. J K Fink. Reactive polymers fundamentals and applications- a concise guide to industrial polymers, William Andrew Publishing, Newyork, USA, 2005.
5. Stanley Middleman, Fundamentals of polymer processing. McGraw-Hill Inc., USA, 1977.
6. Manas-Zloczower and Z. Tadmor, Mixing and compounding-theory and practice. Carl Hanser Verlag, 1994.

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PST220: DESIGNING OF NOVEL POLYMERIC MATERIALS (5:0:0)		
Contact Hours: 5/week		
Course Outcomes: Upon successful completion of this course, the students will be able to		
CO1	Explain the basic concepts of the structure- property-processing correlation of the materials.	**10h**
CO2	Identify and formulate materials for tailor made engineering applications.	
CO3	Explain the role and synergistic effect of additives in polymers	
CO4	Design or develop solutions to evaluate the product performance	
CO5	Develop or design formulation for eco-friendly products.	
Course Content:		
Unit 1	**Polymer & Polymer Blends -** Thermodynamic of polymer blends. Miscibility of Polymers. Immiscible blends, LCST, UCST Transition behavior of blends – T_g, T_m, crystallization, morphology of important commercial polymers	**10h**
Unit 2	Compatibilization and mechanism, Reactive blending. Compatibilizers.	**10h**

	Plastics processing from material engineering point of view, Mixing, kneading, granulation. Properties, stability and application of plastics; Evaluation of degree of miscibility in polymer blends.	
Unit 3	**Effect of additives on properties and processibility of Plastics -** Reinforcement (Long, Short fibers, and Particulate); Plasticizers, Process aids, Lubricants, Impact Modifiers), Surface Property Modifiers (Antiblocking, Antislip agents, Antistaic Agents, Adhesion Promoters)	**10h**
Unit 4	**Optical Property Modifiers** - Transparecy, Opacity, Colour, Fluorescent, Phophorescent, Optical Brightening Pigments), UV Stabilizers, Antidegradants & Stabilizers	**10h**
Unit 5	**Compounding of Rubbers -** Introduction, Compounding Hierarchy, Elastomers Used in Rubber Compounding, Fillers for Rubber, Antidegradants, Processing Agents, Vulcanization. Statistical design of experiments and analysis of results	**10h**

References:

1. J. A. Manson and L.H. Sperling, Polymer Blends and Composites, Plenum Press, New York, 1976.
2. C. Booth and C. Price, Comprehensive Polymer Science, Pergamon Press, Oxford, 1989.
3. Anil K. Bhowmick, Rubber Products Manufacturing Technology, Marcel Dekker, New York, 1994.
4. Roberts A.D., Natural Rubber Science and Technology, Oxford University Press, Oxford, 1988.
5. G. Alliger (Editor), I. J. Sjothun, Vulcanization of Elastomers: Principles and Practice of Vulcanization of Commercial Rubbers, Reinhold Pub. Corp., New York, 1964.
6. J.A. Brydson, Plastic materials, 6th Ed., Butterworth-Heinemann, Oxford, 1995.
7. LA Utracki, Polymer alloys and blends: thermodynamics and rheology, Hanser, Munich,1990
8. DR Paul and S. Newman, Polymer Blends, Academic Press, New York, 1978.
9. Charles B. Arends, Polymer Toughening, Marcel Dekker, New York, 1996.
10. Nobert M Bikales, Mechanical properties of polymers, Wiley-Interscience, Newyork, 1971.
11. Kier M. Finlayson and Melvyn A. Kohudic (Editors), Advances in Polymer Blends and Alloys Technology, Lancaster, Technomic, 1989.

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PST230: POLYMERS STRUCTURE PROPERTY RELATIONSHIPS (5:0:0)		
Contact Hours: 5/week		
Course Outcomes: Upon successful completion of this course, the students will be able to-		
CO1	Explain the fundamental understanding about various structural parameters and its correlations with various properties;	
CO2	Explain the understanding about molecular aggregation behavior, and influence of structure on physico-mechanical properties.	
CO3	Predict material properties based on molecular orientation and additives;	
CO4	Estimate values of various properties by group contributions technique;	
CO5	Select the right polymer for specified applications.	
Course Content:		
Unit 1	**Concepts of Polymer Structure and Properties:** Chemical linkage between repeat units; approach and the concept of chemical structure of polymers (well known polymers' chemical structures to be discussed), stearic regularity of polymer chains. Inter-chain and intra-chain forces of interactions; determination of tacticity and crystallinity. The concept of polymer properties (fundamental, processing and product properties); Typology of polymers (general properties of each family to be discussed), Structural basis for polymers to be- elastomers, fibers and plastics.	**10h**
Unit 2	**Macromolecules in aggregation:** aggregation of polymer chains, structural features of crystallizable polymers, molecular arrangement in crystallites (eg. In PE, syndiotactic vinyl polymers, PTFE, PVA, polyesters and polyamides); the principles of crystallite structure, single crystals of polymers, the morphology of polymers crystallized from melts (spherulites). **Structural influence on various properties:** Optical, Mechanical, Electrical, Thermal and Solubility.	**10h**

Unit 3	**Influence of the Process Variables on the Properties:** Orientation, degree of orientation, measurement of degree of orientation, uni-axial orientation: meaning, change of properties by orientation in amorphous and crystalline polymers; biaxial orientation; quantitative relationships for some physical quantities after orientation like: density, thermal expansion, thermal conductivity, refractive index (birefringence), modulus of elasticity, mechanical damping, generalized stress-strain relationship for polymers. **Effect of various additives on polymer behavior** (to be discussed with some specific examples).	**10h**
Unit 4	**Group contribution on various properties:** Volumetric, Calorimetric, Solubility, Transition temperatures, Cohesive/adhesive and mechanical properties.	**10h**
Unit 5	**Influence of molecular structure to predict the properties of specialty polymers:** water soluble polymers, oil soluble polymers, oil insoluble polymers, resistance to gas permeation, flame retardant polymers, insulating polymer, coating polymer, flexible polymers, water repellant polymers, heat resistant polymers, transparent polymers, adhesive polymers, corrosion resistant polymers. High performance Polymers.	**10h**

References:

1. Van Krevelen, Properties of Polymers: Correlations with chemical structure, Elsevier Pub., NY, 1972.
2. Raymond B Seymour, Structure-property relationships in polymers, Plenum Press, NY, 1984.
3. Patrick Meares, Polymers-structure and bulk properties, Van Nostrand Pub., NY, 1965.

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PST241: POLYMER DEGRADATION AND STABILIZATION (5:0:0)	
Contact Hours: 5/week	
Course Outcomes: Upon successful completion of this course, the students will be able to-	
CO1	Describe the fundamental aspects of polymer degradation
CO2	Explain thermal and photo degradation and their mechanism
CO3	Discuss oxidative degradation of polymers
CO4	Explain different stabilizers, antioxidants and fire retardants used in polymers

CO5	Solve the problems related to polymer degradation	
Course Content:		
Unit 1	**Introduction to Polymer Degradation** The practical significance of polymer degradation, Polymer durability, Polymer stabilization, recycling of polymers, degradable polymers and the plastics litter problem, fire hazard of polymers, technological testing procedures, the scientific study of polymer degradation process.	**10h**
Unit 2	**Thermal degradation** - Experimental methods, classification of thermal degradation reactions, radical depolymerisation reactions, non-radical depolymerisation reactions, cyclization reaction with elimination. **Photo-degradation -** Introduction, photodegradation of polyolefins, acrylates and methacrylates, copolymers of methyl methacrylate and methyl vinyl ketone, polystyrene, polymers with heteroatoms in the main chain, condensation polymers, photo oxidation.	**10h**
Unit 3	**Oxidation of polymers** - Auto oxidation, physical effects of auto oxidation in polymers, the oxidation chain reaction, chemical changes in polymers during oxidative degradation, the effect of chemical structure on oxidation rate, the effects of physical structures of polymers on their rates of deterioration, oxidative degradation of commercial polymers, degradation during melt processing, degradation at high temperatures, during service, sanitization by pigments, mechano- oxidation.	**10h**
Unit 4	**Antioxidants and stabilizers** - Mechanism of antioxidant action, chain breaking antioxidants, preventive antioxidants, synergism and antagonism, chain breaking-acceptor antioxidants, metal deactivators, UV screens and filters, stabilization of polymers during manufacture and in service, melt stabilization, thermal oxidative stabilization, polymer bound antioxidants, and UV stabilizers. **Degradation and the fire hazard -** The flammability problem, flammability testing, the burning cycle, additive and reactive fire retardants, phosphorus compounds, antimony trioxide, aluminum trioxide, compounds of boron.	**10h**
Unit 5	**Degradation in special environments** - Polymers under stress, degradation in polluted atmospheres, nitrogen dioxide, sulphur dioxide, degradation at high	**10h**

	temperatures, ablation, mechanical and ultrasonic degradation, quantitative aspects of ultrasonic degradation, mechanism of bond scission, quantitative aspects of changes in molecular weight, degradation by high energy radiation, chemical changes in polymers, G values, radiation protection, hydrolytic degradation and recycling of polymers by hydrolysis.	

References:

1. G.Scott, Elsveir, Atmospheric oxidation and antioxidants, London and New York, 1965
2. R.T. Conley, Thermal stability of polymers, Dekker, 1970.
3. B.Ranby and J.F. Rabek, Photo-degradation, Photo oxidation and photostabilisation of polymers, Wiley, 1975.
4. G Scott, N. Grassie, The Role of Peroxides in the Photodegradation of polymers, developments in polymer degradationApp. Sci. Pub., London, chapter 7. 1979
5. G.Scott, Scott Mecahnism of antioxidatnt action, developments in polymer stabilization, App. Sci. Publication. London, Chapter 1. 1981
6. J. W. Lyons, The chemistry and uses of fire retardants, Wiley and sons, 1970.
7. R.M. Harrison and C.D. Holman, Ozone pollution in Britain., Chem. In. Brit., 18, 563, 1982.

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PST242: POLYMER PRODUCT AND MOULD DESIGN (5:0:0)		
Contact Hours: 5/week		
Course Outcomes: Upon successful completion of this course, the students will be able to-		
CO1	Explain basic principles of plastic product design.	
CO2	Apply creep curve concepts for designing, assess the mechanical behavior of composites and explain the fracture behavior of plastics.	
CO3	Explain the mold making and mold features.	
CO4	Explain intermediate mold design aspects.	
CO5	Design and draw simple molds.	
Course Content:		
Unit 1	**Introduction**– Material selection based on end use requirement of various products; principles of product design.	**8h**

	Product Design Features and design steps: Features: inside sharp corners, Wall thickness, holes, shrinkages, bosses, ribs, threads, draft angle, gussets, parting lines, rims, molded inserts, undercuts, tapers. Design steps: Engineering and pseudo plastic design	
Unit 2	**Design for stiffness**– Use of creep curves, methods to improve stiffness. Analysis of thermal stresses and strains for designing plastic products. Mechanical behavior of composites: Design properties of composites. Mechanical behavior of composites - aspect ratio, volume fraction), Analysis of continuous fiber composite: longitudinal properties, equilibrium equation, geometry of deformation equation, stress strain relationships. Properties perpendicular to longitudinal axis: equilibrium conditions, geometry of deformation equation, stress strain relationships. Concept of stress concentration factor, Energy approach to fracture, stress intensity approach to fracture, general fracture behavior of plastics, creep fracture of plastics, crazing and fatigue in plastics.	**12h**
Unit 3	**Mold design**: Introduction to mold making, general mold construction, feeding system cooling system, ejection systems.	**10h**
Unit 4	**Intermediate mold design**: Splits, side cores and side cavities, molding internal under cuts, mold for threaded components	**10h**
Unit 5	**Aspects of practical mold design:** procedure for designing injection mold, checking mold drawing, worked examples.	**10h**

References:

1. R.D.Beck, Plastics product design, Van Nostrand – Reinhold
2. R.J.Crawford, Plastics Engineering, 3rd edition, Butterworth Heinemann.
3. R.G.W.Pye, Injection mold design, Fourth edition, East west Pvt. Ltd., New Delhi,1989.
4. Dubois and Pribble, Plastics Mold Engineering Hand book, Chapman & Hall, 2007
5. E. Miller, Plastics product design hand book – Part A and Part B., Marcel Dekker, N.Y.
6. Levy & Dubois, Plastics Product Design Engineering Hand Book, Champman and Hall, 2007.

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PST243: DESIGN OF ADVANCED POLYMER COMPOSITES (5:0:0)
Contact Hours: 5/week

Course Outcomes: Upon successful completion of this course, the students will be able to		
CO1	Explain the basics of composites and select a suitable matrix material	
CO2	Select a suitable reinforcement to meet the end product requirement.	
CO3	Explain composite processing techniques.	
CO4	Discuss the performance of polymer composites and failure mechanisms.	
CO5	Explain designing aspects of polymer composites.	
Course Content:		
Unit 1	**Introduction -** Definition, reason for composites, classifications of composites, advantages and disadvantages of composites. **Thermoplastic Matrix -** Functions of matrix, raw materials, physical and chemical properties, thermal and mechanical properties. **Thermoset Matrix -** Epoxy; Curing reactions, hardener, gel time, viscosity modifications, Prepeg making. Unsaturated polyester resin; Catalyst, curing reactions, viscosity modifier. Alkyd resin, vinyl ester, cyanate ester, polyimides, physical and chemical properties, thermal behaviour, mechanical properties and uses.	**10h**
Unit 2	**Reinforcements -** Introduction, Functions of fillers, types, properties, chemistry and applications of fillers such as silica, titanium oxide, talc, mica, silicon carbide, graphite. Flakes - Both and natural and synthetic should be considered. Fibers-Natural (silk, jute, sisal, cotton, linen) and synthetic, short and long fibers, general purpose and high performance fibers, organic and inorganic fibers - Properties, structure and uses; Glass fiber-classifications, chemistry, manufacturing process. Properties and uses of Nylons, Carbon, Aramid, Boron, aluminium-carbide fibres. **Coupling agents -** Function, chemistry, methods of applications, advantages and disadvantages.	**10h**
Unit 3	**Processing of thermoplastic composites -** Types of processing methods, matched die molding, solution, film, lamination, sandwich. Processing conditions, advantages and disadvantages. **Fabrications of thermoset composites-** Hand lay up method, match die molding, compression and transfer molding, pressure and vacuum bag process, filament	**10h**

	winding, pultrusion, RIM, RRIM, VARTM & VERTM, Injection moulding of thermosets, SMC and DMC, Advantages and disadvantages of each method.	
Unit 4	**Factors influencing on performance of the composites -** Aspect ratio, void content, length of the fiber, nature of the fiber, structure property relationship between fiber and matrix, modifications of the fiber surface, degree of interaction between and fiber and matrix, wetting behavior, degree of cross linking. **Testing of composites -** Destructive and non-destructive tests; Destructive-tensile, compression, flexural, ILSS, impact strength and HDT. The basic concepts of fracture mechanisms.	**10h**
Unit 5	**Composite product design -** Introductions, Design fundamentals, definitions, structure-material-design relationships, design values and design constraints, uncertainty in product design, constitutes of composite product, design process, decision making in design, design methodologies, material considerations in composite design, numerical problems.	**10h**

References:

1. George Lubin, Hand book of composites ,Van Nostrand Reinhold Company Inc, New York 1982.
2. L.C. Hollaway, Polymers and Polymer Composites in Construction, Thomos Telford ltd., London,UK, 1990
3. John C. Bittence, Fran Cavern, Engineering Plastics and Composites, Materials data series, 2nd edition, ASM International, 1990
4. Charles A. Harper, Handbook of Plastics, Elastomers and Composites, Illustrated edition, McGraw Hill Professional, 2002
5. Rosato, Designing with Reinforced composites- Technology-Performance, Economics, 2nd Ed. Hanser publications ,Newyork,1997.
6. Leif A. Carlssen. And Joahn W. Hillispie, Delwane Composite design Encyclopedia (Vol 3) Processing and Fabrication / Technology, Technomic Publishing Ah. Lancaster U.S.A.
7. Nicholas P. Cheremisinoff and Paul N. Cheremmisinoff, Fiber glass Reinforce Plastics and Composites, Noyes Publications, N.J. U.S.A. 1995.
8. Thomas J. Drozdr, Composite applications – the future is now, Society of Manufacturing Engineers, Michigan, 1989.

9. Y.C. Ke, P. Strove and F.S. Wang, Polymer layered silicate and silica nano composites. Elsevier, 2005.
10. Sanjay K Mazumdar, Composite manufacturing, materials, product and process engineering, CRC Press, London, 2002.
11. Vishu Shah, Hand Book of Plastics Testing Technology, 2nd edition, John Wiley & Sons, Inc NY. 1998.

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PST244: FABRICATION OF INTRINSIC CONDUCTING POLYMERS (5:0:0)		
Contact Hours: 5/week		
Course Outcomes: Upon successful completion of this course, the students will be able to-		
CO1	Explain the basic concepts of conducting polymers and methods of measurements of electrical properties	
CO2	Explain the conducting mechanisms and factors effect on conducting properties	
CO3	Explain the synthesis, properties and applications of conducting polymers	
CO4	Explain the fundamental and applications of electro active polymers.	
Course Content:		
Unit 1	Electrical properties measurements - Introduction to conducting polymers, definitions, classifications, practical significance and applications of conducting polymers, Measurement of properties - conductivity, volume and surface resistivity, dielectric strength, dielectric constant, dissipation factor, capacitance, break down voltage, arc resistance and impedance.	10h
Unit 2	Conductor, semiconductor and factors affecting on electrical properties. Conductive mechanism- percolation theory, charge carrier transport in composites, electrical contacts between filler particles and different conduction models Factors affecting – fillers nature, size, shape, nature of polymers, dispersion of the fillers, morphology of the fillers, temperature, frequency/voltage and environmental conditions	10h
Unit 3	Electrically conducting polymers - Introduction, prototype conducting polymer and	10h

	electrochemistry of conducting polymer films, co-polymers and composites of conducting polymers, processable conducting polymers. Metal ion containing polymers, solid polymer electrolyte, characteristics properties and applications of electrically conductive polymers.	
Unit 4	Synthesis, characteristic properties and applications of conducting polymers Poly acetylene, polyaniline, polypyrrole and polythiophene. Fabrication of conducting polymer composites - Melt mixing method, solution, emulsion, solution interfacial and insitu polymerization methods. Methods of measurements of electrical properties and structure-property relationship.	10h
Unit 5	Electro active polymers - Filled polymers, EMI shielding, conductive coating, signature materials, inherently conductive materials, doping, conducting mechanisms. Applications; Rechargeable batteries, electro chromic devises, sensors, microelectronics, photoconductive polymers, polymers in fiber optics, polymers in nonlinear optics, Langmuir-Blodgett films, peizo and pyro electric polymers and their applications.	10h

References:

1. Conductive polymers and plastics. Edited by James M. Margolis, Chapman and Hall Ltd., London, 1989.
2. Handbook of Conducting Polymers, Vol 1&2 (Ed.: T. A. Skotheim), Marcel Dekker, New York, 1986.
3. Handbook of Organic Conductive Materials and Polymers (Ed.: H.S. Nalwa), Wiley, New York, 1997; Handbook of Conducting Polymers (Eds.: T. A. Skotheim, R. L. Elsenbaumer, J. F. Reynolds), 2^{nd} ed., Marcel Dekker, New York, 1998

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PST251: FIBER TECHNOLOGY (5:0:0)	
Contact hour: 5/week	
Course Outcome: Upon successful completion of this course, the students will be able to	
CO 1	Explain the science and technology of spinning process
CO 2	Characterize and Identify the fiber forming polymers.

CO 3	Discuss the concept and design principles of protective textiles	
CO 4	Explain the theoretical background and applications of medical textiles	
CO 5	Describe the concept of sportswear and smart textile	
Course Content:		
Unit 1	**Production of fibers** Principle, technology, advantages and disadvantages of the following techniques; Melt spinning, Dry spinning, wet spinning process, Electro spinning techniques. Drawing of fibers.	**10h**
Unit 2	**Requirement of fiber forming polymers** Crystallinity and orientation. X-ray diffraction measurement of Crystallinity. orientation, crystal size, small angle X-ray scattering. Measurement of density of fibres, Density Crystallinity, Infrared spectroscopy for determination of orientation and crystallinity. Optical microscopy for measurement of birefringence. Internal and surface structure by electron microscopy. Thermal methods DSC TGA and TMA for structural investigation. Morphological structure of cotton, wool, silk, regenerated cellulose, polypropylene, polyester, nylon and polyacrylonitrile.	**10h**
Unit 3	**Protective clothing -** Clothing requirements for thermal protection, ballistic protection, UV-protection, protection from electro-magnetic radiation and static hazards, protection against microorganisms, chemicals and pesticides. Design principles and evaluation of protective clothing.	**10h**
Unit 4	**Medical Textiles -** Textiles in various medical applications. Application oriented designing of typical medical textiles (sutures). Materials used and design procedures for protecting wounds, cardiovascular and other applications	**10h**
Unit 5	**Sportswear -** Clothing requirements for different sports. Development of highly functional fibers, yarns and fabrics for temperature control and moisture management. Stretch, bulky and light weight fabrics. **Stimuli sensitive intelligent textiles** - Production, properties and applications. Smart textile incorporating functional devices.	**10h**

References:

1. Kostikov, V. I. Fibre science and technology; Chapman & Hall: London, 1995.
2. Mark, H.F., Atlas, S.M., Man-made fibers; Science and Technology, Interscience Publishers: New York, 1967.
3. S.P Mishra, A Text book of Fiber Science & Technology, New age International Publishers, New Delhi, 2005.

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PST252: ADVANCED RUBBER TECHNOLOGY (5:0:0)		
Contact Hours: 5/week		
Course Outcomes: Upon successful completion of this course, the students will be able to		
CO 1	Explain the additives, processing and characterization of rubber compound	
CO 2	Design/develop rubber compounds to meet specific criteria.	
CO 3	Analyze and interpret the effect of mixing process parameters.	
CO 4	Explain different vulcanization techniques	
CO 5	Characterize, analyze and interpret the results of rubber compound testing	
Course Content:		
Unit 1	Mechanistic understanding of rubber processing (chemistry behind each process); Mechanism of curing (for different types of curing); Function of different rubber additives. Characterization of rubber compound – methods most prevalent in industry.	**10h**
Unit 2	**Compounding and Compounding Ingredients -** Overview of the science of compounding, Review of the properties and applications of natural and synthetic rubbers, Major classes of additives i.e., fillers, oils, plasticizers, processing aids, anti-degradents and curative systems, Examples of how compounds are designed to meet the requirements of various end applications will be discussed. **Compounding and Mixing for Specific Applications** - Mixing procedures for specific compounds, illustrating the variations that follow from the nature of the ingredients, application and the equipment available, Relationship between compounding and successful mixing is emphasized.	**10h**

	Compounding and Mixing of Tire Compounds - An outline of the various tire components, required properties in the finished tire, Resultant compositions and mixing procedures; Effect of various compounding ingredients on processing behavior of the Rubber compound; effect of various elastomers, fillers, plasticizers and process aids.	
Unit 3	**Mixing Process** - An account of the mixing process from raw material acceptance to packaging of the mixed compound, raw material specification and testing, weighing and feeding of ingredients, the mixing process (incorporation, distribution, and dispersion), flow behavior in mixers, modeling the mixing process, process variables (e.g. temperature control, basic mixing procedures, natural rubber mastication, and dump criteria), operating variables (e.g. rotor speed, ram pressure, chamber loading), control of the mixing process, discharge, shaping and cooling. **Mixing Cycles and Procedures** - Cost of internal mixing, unit operations in mixing, single-pass versus multiple-pass mixing, types of mix cycle, mill mixing. **Rubber Mixing Equipment -** Basic mixer design, Review of developments in rotor design. **Continuous Mixing of Rubber** - An outline of developments in extruder mixing.	**10h**
Unit 4	**Vulcanization** - Equipment, Compounding, desired flow properties and cure rates, for the batch processes of molding and autoclave vulcanization, for continuous vulcanization of hose, profiles, wire coverings and calendared products.	**10h**
Unit 5	**Physical Testing of Rubber-** Tensile, hardness, thermal, dynamic mechanical, electrical testing of vulcanizates, tests for dispersion and contamination, tests to identify surface exudation. **Processibility Testing of Rubber Compounds** - Review the tests and testing equipment used to assess the processibility of mixed compounds i.e., the Mooney test, capillary rheometer, torque rheometer, oscillating disc cure meters, rotor less cure meters, dynamic mechanical rheological testers	**10h**

	(especially the RPA 2000) and stress relaxation instruments, Correlation (or its lack) between ODR and MDR cure times will be discussed, IISRP, comparative evaluation of processibility tests, 'Which is the Best Processibility Tester?' will be addressed.	

References:

1. Rodgers, B. Rubber compounding: chemistry and applications; Marcel Dekker: New York, 2004
2. Gent, A. N. Engineering with rubber how to design rubber components; 2nd ed.; Hanser; Munich, 2001.
3. Morton, M., Rubber technology, 2nd Ed.; Van Nostrand Reinhold: New York, 1973.
4. Freakley, P. K., Rubber processing and production organization; Plenum Press: New York, 1985.
5. Brydson, J. A., Rubbery materials and their compounds; Elsevier Applied Science, London, 1988.
6. Barlow, F. W., Rubber compounding: Principles, materials, and techniques; M. Dekker: New York, 1988.
7. J.E. Mark, B. and Erman. F.R. Eirich, Science and Technology of Rubber, Elsevier Academic Press, UK, Third Edition, 2005.
8. N.R. Legge, G.Holden and H.E. Schroeder, Thermoplastic elastomers, 2nd edition, Hanser Verlag, Munich, 1996.
9. Blow, C. M.; Hepburn, C. Rubber technology and manufacture; 2nd ed.; Butterworth Scientific: London, 1982.
10. Alliger, G. and Sjothun, I.J., Vulcanization of elastomers: Principles and practice of vulcanization of commercial rubbers, Reinhold Pub. Corp., New York, 1964.

PST253: POLYMER MEMBRANES AND DRUG DELIVERY (5:0:0)	
Contact Hours: 5/week	
Course Outcomes: Upon successful completion of this course, the students will be able to	
CO 1	Explain the classification, behavior and selection of polymeric membranes
CO 2	Characterize polymeric membranes

CO 3	Explain the applications of polymeric membranes	
CO 4	Explain the principles of self-assemblies for drug delivery applications	
CO 5	Explain the role of polymers in controlled release of drug	
Course Content:		
Unit 1	**Fundamentals of Membranes -** Introduction to membranes– definition-classification of membranes- Homogenous dense membranes- Heterogeneous asymmetric membranes –thin film composite membranes – liquid membranes-ion exchange membranes –polymer selection for development of membranes-polymer selection for development of membranes polymer property-strength-viscosity-chemical resistance-processing temperature- factors membrane performance.	**10h**
Unit 2	**Development and Characterization of Membranes -** Development of polymer membranes-modification–blending – crosslinking – grafting - copolymerization-characterization of membranes-solution techniques; viscosity, density, ultrasonic velocity-thermal methods; TGA, DSC, TMA – spectroscopy methods; UV, FT-IR, NMR-optical methods; SEM, TEM and XRD.	**10h**
Unit 3	**Application of Membranes -** Various applications and uses of membranes; Micro filtration – ultra filtration – Reverse osmosis - Gas permeation - Pervaporation - Nano filtration - Dialysis-electro dialysis.	**10h**
Unit 4	**Self-Assemblies as Promising Vehicles for Drug Delivery -** Introduction-various self assembled aggregates as carriers-surfactants Micelles-Liposomes-polymeric aggregates–polymeric Micelles-polyion complexes-functional properties of polymeric carriers- morphological criteria-solubility and stability-Biocompatibility-drug loading and releasing characteristics-Biological aspects – pharmacokinetics at the systemic level – cellular uptake – release of drugs in the cell.	**10h**
Unit 5	**Role of Polymers in Controlled Release of Drug Delivery** Introduction- currently available polymers; diffusion-controlled systems-solvent-activated systems–chemically controlled systems – Magnetically controlled systems –soluble polymers as drug carriers: pinocytosis- Ideal soluble polymers – Biodegradable or bioerodible polymers: Drug release by matrix solubilization-	**10h**

	Erodible diffusional systems – Monolithic systems - Mucoadhesive polymers – polymer containing pendent bioactive substituents- Mmatrix systems.	

References:

1. Kaustubha Mohanty, Mihir K. Purkait. Membrane Technologies and Applications, CRC Press, London, 2011.
2. Vasant V. Ranade, A. Mannfred Hollinger, Drug Delivery Systems, 2nd Edition, CRC Press, Boca Raton, Florida, 2003.
3. RYM Huang. Pervaporation membrane separation processes. Elsevier Publications, Amsterdam, 1991.
4. Petrmunk and T.M. Aminabhavi. Introduction to Molecular Science, 2nd edition, Wiley Interscience, New York, 2002.

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PST254: SPECIALTY AND FUNCTIONAL MATERIALS (5:0:0)		
Contact Hours: 5/week		
Course Outcome: Upon successful completion of this course, the students will be able to:		
CO 1	Explain the basic concepts of specialty and functional materials	
CO 2	Classify and describe different types of specialty polymers	
CO 3	Describe the applications of specialty polymeric materials	
CO 4	Select a suitable material and fabrication technique of specialty polymers for specific applications	
Course Content:		
Unit 1	**Conducting polymers - C**hemistry, Preparation, conducting mechanism, properties and uses (LED market, future of lighting, smart materials or sensors) of polyaniline and polypyrrole.	**10h**
Unit 2	**High Temperature and fire resistant polymers:** Importance, methods to improve thermal stability and fire resistance, properties and applications of high temperature and fire resistant polymers **Liquid crystal polymers:** Smectic, nematic, cholestric crystals, theromotropic main chain liquid crystal polymers, side chain liquid crystal polymers, chiral nematic liquid crystal polymers, properties and applications of commercial LCPs.	**10h**

Unit 3	**Polymers in photo-resist applications:** Negative photoresists, positive photoresists, plasma developable photoresists, photoresists applications for printing. **Functional fillers**: Enhancement of fire retardancy, Modification of electrical and magnetic properties, Modification of surface properties, Enhancement of processability; **Functional colorants**	**10h**
Unit 4	**Ionic Polymers:** Classification, Synthesis, Properties **(**Ionic cross linking, ion-exchange, hydrophilicity) of ionic polymers. Ionomers and polyelectrolytes: types, properties and applications. **Synthetic polymer membranes:** Types of membranes, Membrane preparation, membrane modules, applications.	**10h**
Unit 5	**Hydrogels:** Classification, Synthesis, Characterization and applications **Shape memory polymers:** Classification, thermomechanical cycle, molecular mechanism, activation method, applications of SMPs; **Micro encapsulation:** Morphology, core and shell materials, microencapsulation techniques, release mechanism and applications	
Reference: **1.** Plastics Technology Hand Book, Manas Chanda and Salil K Roy (4th edition), CRC press, New York.		

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PST255: NANOSTRUCTURED MATERIALS (5:0:0)	
Contact Hours: 5/week	
Course Outcomes: Upon successful completion of this course, the students will be able to	
CO1	Explain the fundamentals of nanostructured materials,
CO2	Synthesize and characterize the nanostructured materials.
CO3	Prepare polymer nanocomposites for tailor made applications.
CO4	Solve the problems related to health issues
Course Content:	

Unit 1	**Nanostructured materials -** Introduction, basic of Nanoparticles, Nanowires, Nanorods, Nanoplatelets, Nanoclusters, Solid solutions.	**10h**

	Classification, synthetic routes for nanoparticles production- super critical fluid based particle production, droplet and aerosol techniques, gas atomization approaches, dendrimers, block copolymers, self-assembly, block copolymer phase diagram, Block copolymer thin films,hyper branched polymers or star polymers, molecular imprint polymers, nano oxides, nanowires, nanotubes and nanofibres, polymer nanofilm, applications of polymeric nanoparticles.Bottom up and top down approaches and nanofabrication.	
Unit 2	**Polymer-inorganic nanocomposites -** Introduction of nanotechnology and polymer nanocomposites, the difference between nanocomposites and traditional filler enhanced polymers, the structure and classification of polymer nanocomposites, different types of nano fillers, one dimensional, Two dimensional and Three dimensional nanostructured materials, nanoclay- introduction, structure, chemistry and its modification with surfactants, preparative methods and structure of polymer/clay nanocomposites, types of polymers used for polymer/ clay nanocomosites preparation, material properties of polymer/clay nano composites, melt rheology and processing operations of nanocomposites, characterization of nanocomposites. Nanocomposites of polymers and inorganic particles, synthesis and properties. Major progress over the past one and half decades.	**10h**
Unit 3	**Carbon nanomaterials -** CNTs- Structural aspects, single walled and multi walled nanotubes, preparation of nano tubes: carbon arc process, catalytic assisted pyrolysis, laser technique, electro chemical method, purification of carbon nano tube, properties of nano tubes, surface modification of CNTs, application of nanotubes. Graphite nanofibre, Graphene oxide- chemistry, types, preparation and surface modification and properties. Applications of Nanomaterials: Catalysis, electronic, aerospace, automotive, surface coatings, magnetic, optical and medicine.	**10h**
Unit 4	**Nanocomposites of carbon nanotubes -** Introduction, carbon nanotube-metal matrix composites, carbon nanotube –ceramic-matrix composites – properties and uses. CNT-polymer-matrix composites – methods of fabrication, characterization, and their uses. Factorsinfluencing the performances of nanocomposites. Graphene	**10h**

	oxide – polymer composites - fabrication, characterization and their uses. **Conducting polymeric nanomaterials -** Introduction to conducting polymers, mechanism of conduction in nanocomposite, effect of dopants on conductivity, methods of synthesis of polymeric nanomaterials, structure-property relationship, polymeric nanomaterials for electrical and electronic applications.	
Unit 5	**Application of Nanotechnology -** Nanotechnology for waste reduction and improved energy efficiency, nanotechnology based water treatment strategies. Nanoporous polymers and their applications in water purification, Nanotoxicology. Use of nanoparticles for environmental remediation and water treatment. Case studies and Regulatory needs. **Polymeric nanoparticles for drug and gene delivery -** Introduction, transport phenomenon and mechanism, features of polymeric materials, preparation and characterization of nanoparticles, recent developments in nanoparticles technology, nanoparticles for drug and gene delivery applications	**10h**

References:

1. H.S.Nalwa (ed).-Encyclopedia of nanoscience and nanotechnology,American Scientific Publisher, USA, Vols. 1-10, 2004.

2. Tapas Kuilla, Sambu Bhadra Dahu Yao, Nam Hoon Kim,Saswata Bose, Joong Hee Lee, Recent advances in graphene based polymer composites - Progress in Polymer Science 35(2010) 1350-1375.

3. Editors: S. Thomas, G.E. Zaikov and S.V. Valsaraj, Recent advances in polymer nanocomposites, Leiden, Boston, 2009.

4. Editors: S.Thomas, G.E.Zaikov, Progress in Polymers Nanocomposites Research , Nova publishers, USA, 2008. web site address: novapublishers.com

5. Y.C.Ke, P.Stroeve, F.S.Wang, Polymer layered silicate and silica nano composites, Elsevier, 2005.

6. B.K.G. Theng. Formation and properties of clay-polymer complexes. 2nd ed., Elsevier, Amsterdam, 2012.

7. B.K.G. Theng. Chemistry of clay-organic reactions. , Adam Hilger, London, 1974.

8. V.Chirala, G.Marginean, W.Brandl and T.Iclanzan, Vapour grown carbon nanofibres-poly propylene composites and their properties in Carbon nanotubes edited by V.N. Popov and

P.Lambin, p.227, Springer, Netherlands, 2006.

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PST26L: POLYMER PROCESSING AND TESTING LAB (0:0:1.5)	
Contact Hours: 3/week	
Course Outcomes: Upon successful completion of this course, the students will have an ability to	
CO1	Explain the processing and testing related experimental procedures along with its implications and to communicate it effectively
CO2	Produce polymer products and to test them using modern tools
CO3	Analyze, interpret and report the experimental data suitably
List of Experiments: **Part-A: Compounding & Processing**	
1	Automatic injection molding: different materials, molds and optimization of cycle time.
2	Rubber compounding using Haake batch mixer.
3	Blown-film (cross-head) extrusion.
4	Fabrication of Polymer Composites (hand lay-up, SMC, DMC).
5	Rubber compounding for at least two specific product formulations.
6	Compression Molding (rubbers, thermosets, blends).
7	Additive manufacturing.
8	Ultrasonication and solvent casting.
9	Extrusion of plastic strands and pelletization*; Extrusion of rubbers.
10	Effect of mastication level on natural rubber compounds*; Effect of additives, curative system and process variables on properties of rubber products.
11	Hand operated injection molding*
12	Hand operated blow molding*
13	Pneumatic injection molding*
14	Pneumatic blow molding machine*
Part-B: Testing	

1	Tensile tests (i) Stress-Strain and (ii) creep and stress relaxation for- Plastics, Rubbers and Composites.
2	Flexural tests (Plastics)
3	Izod impact strength (Plastics) [notched and un-notched, for different materials]
4	Thermal properties (Plastics) (i) heat distortion temperature (HDT) and (ii) vicat softening temperature (VST)
5	Electrical properties (Plastics) (i) Break down voltage and (ii) Dielectric strength- for various thin sheet materials.
6	Determination of melt flow index and power-law index for different plastics.
7	Flammability Testing.
8	Mooney viscosity and curing characteristics of rubber compounds[#]
9	Crosslink density and compression set of rubbers[#]
10	Durometer hardness tests (A) Plastics, (B) Rubbers*; and Resilience studies of rubbers*
11	Abrasion resistance (A) Plastics and (B) Rubbers*
12	Flex-fatigue strength (Rubbers)*

Note: (i) *Mandatory for students of other than B.E. PST and (ii) [#]to be performed with the help of rubber industries

References:

1. Vishu Shah, Handbook of plastics testing technology, John Wiley, NewYork, 2007
2. Processing Technology Laboratory Manual (Department Of PST).
3. Isayev, Injection molding and compression molding fundamentals, Marcel Dekker, 2010
4. Alan Griff, Plastics Extrusion Technology, Krieger Publishing Company, 1996
5. Rosato and Rosato, Injection Moulding Hand book, Hanser Publishers, 2010.
6. Rosato and Rosato, Blow Moulding Hand book, Hanser Publishers, 2010.
7. Ed.Corish, Concise Encyclopedia of Plastics Processing and applications, Pergamon Press, 1996.
8. Relevant ASTM standards for testing methods.

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