JSS MAHAVIDYAPEETHA

Sri Jayachamarajendra College of Engineering

JSS Technical Institutions Campus, Mysuru-06

(An Autonomous Institution Affiliated to Visvesvaraya Technological University, Belagavi)

Detailed syllabus and Scheme of Teaching / Examination for

B.E. in Polymer Science and Technology (III to VIII semesters)

Applicable for students admitted in 2014 / entered to third semester in 2015

(Revised in 8th BOS meeting held on 03/09/2016)

Credit details

Semester	Credits
I	25.0
II	25.0
III	27.0
IV	27.0
V	27.0
VI	27.0
VII	20.0
VIII	22.0
TOTAL	200.0

Sri Jayachamarajendra College of Engineering

Vision

Be an international leader in engineering education, research and application of knowledge to benefit society globally.

Mission

M1: To synergistically develop high-quality manpower and continue to stay competitive in tomorrow's world.

M2: To foster and maintain mutually beneficial partnerships with alumni, industry and government through public services and collaborative research;

M3: To create empowered individuals with sense of identity.

Department of Polymer Science and Technology

Vision

To excel in Polymer engineering education and research, to serve as valuable resource for multi-faceted industry and society.

Mission

1. To provide well balanced curriculum and conducive environment to excel in polymer and allied engineering disciplines.
2. To promote cutting edge polymer research by offering state-of-the-art facilities.
3. To undertake collaborative projects for long term interactions with academia and industries.

Program:

Bachelor of Engineering in Polymer Science and Technology (B.E. PST)

Program Outcomes (POs):

Engineering Graduates will be able to-

PO1 Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2 Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3 Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4 Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5 Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6 The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7 Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8 Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9 Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10 Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11 Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12 Life-long learning: Recognize the need for, and have the preparation and ability to

engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs):

Graduates receiving the Bachelor of Engineering in Polymer Science and Technology will be able to-

PSO1 (Macromolecules):

Apply the basic concepts of chemistry, physics, structure-property relationship and thermodynamics of macromolecules to design novel polymeric materials and composites.

PSO2 (Rheology):

Apply the knowledge of transport process to solve rheological issues in polymer processing and mold design.

PSO3 (Quality Control):

Apply the knowledge of polymer testing and characterization for quality control.

Program Educational Objectives (PEOs):

PEO1: Provide graduates with strong fundamentals of science and engineering for a successful career in Polymer Science & Technology.

PEO2: Enable graduates for higher education and innovative research to solve multidisciplinary issues.

PEO3: Equip graduates with technical skills and moral values for being responsible individuals.

Program Specific Criteria (PSC):

- Apply chemistry, physics to understand structure, properties, rheology, processing, performance of polymeric materials systems, for selection and design of suitable components and process to address the concerned issues.
- Career development of members through research, consultancy and professional activities.

- Provide collaborative learning opportunities through professional societies, industries, institutes and alumni fraternity for promoting PST education along with professional growth of associated individuals.

SRI JAYACHAMARAJENDRA COLLEGE OF ENGINEERING (SJCE), MYSURU 570006

Scheme of Teaching and Examination for B.E (Polymer Science and Technology)

Scheme revised in 2015

Scheme 2014-18: OUTCOME BASED CURRICULLUM

SEMESTER III

Sl. No.	Subject code	Course title	Teaching department	Credits				Contact hours per week	Marks			Exam duration in hours
				L	T	P	Total		CIE	SEE	Total	
1	MA310B	Engineering Mathematics–III (Numerical Methods)	MAT	3	1	0	4	5	50	50	100	3
2	PT310	Inorganic and Physical Chemistry	PST	4	0	0	4	4	50	50	100	3
3	PT320	Organic Chemistry	PST	4	0	0	4	4	50	50	100	3
4	PT330	Polymer Chemistry	PST	4	0	0	4	4	50	50	100	3
5	PT340	Thermodynamics	PST	4	0	0	4	4	50	50	100	3
6	PT350	Transport Phenomena in Materials Engineering-I	PST	4	0	0	4	4	50	50	100	3
7	PT36L	Organic Chemistry Lab	PST	0	0	1.5	1.5	3	50	00	50	-
8	PT37L	Fluid Mechanics Lab	PST	0	0	1.5	1.5	3	50	00	50	-
9	HU310	Constitution of India	Humanity	-	-	-	0	2	50	0	50	-
Total							27.0	33	-		750	-

SRI JAYACHAMARAJENDRA COLLEGE OF ENGINEERING (SJCE), MYSURU 570006

Scheme of Teaching and Examination for B.E (Polymer Science and Technology)

Scheme revised in 2015

Scheme 2014-18: OUTCOME BASED CURRICULLUM

SEMESTER IV

Sl. No.	Subject code	Course title	Teaching department	Credits				Contact hours per week	Marks			Exam duration in hours
				L	T	P	Total		CIE	SEE	Total	
1	MA310A /MA410A	Engineering Mathematics–IV (Fourier Series, Integral Transforms and Applications)	MAT	3	1	0	4	5	50	50	100	3
2	PT410	Material Science and Engineering	PST	4	0	0	4	4	50	50	100	3
3	PT420	Polymer Physics	PST	4	0	0	4	4	50	50	100	3
4	PT430	Polymer Manufacturing Technology	PST	4	0	0	4	4	50	50	100	3
5	PT440	Polymerization Kinetics	PST	4	0	0	4	4	50	50	100	3
6	PT450	Transport Phenomena in Materials Engineering-II	PST	4	0	0	4	4	50	50	100	3
7	PT46L	Physical Chemistry Lab	PST	0	0	1.5	1.5	3	50	00	50	-
8	PT47L	Chemical Engineering Lab	PST	0	0	1.5	1.5	3	50	00	50	-
9	HU410	Environmental Studies	ENV	-	-	-	0	2	50	0	50	-
Total							27.0	33	-		750	-

SRI JAYACHAMARAJENDRA COLLEGE OF ENGINEERING (SJCE), MYSURU 570006

Scheme of Teaching and Examination for B.E (Polymer Science and Technology)

Scheme revised in 2015

Scheme 2014-18: OUTCOME BASED CURRICULLUM

SEMESTER V

Sl. No.	Subject code	Course title	Teaching department	Credits				Contact hours per week	Marks			Exam duration in hours
				L	T	P	Total		CIE	SEE	Total	
1	PT510	Rubber Technology	PST	4	0	0	4	4	50	50	100	3
2	PT520	Rheology of Polymers	PST	4	0	0	4	4	50	50	100	3
3	PT530	Polymer-Structure Property Relationship	PST	4	0	0	4	4	50	50	100	3
4	PT540	Processing Technology-I	PST	4	0	0	4	4	50	50	100	3
5	PT550	Compounding Technology	PST	4	0	0	4	4	50	50	100	3
6	PT560	Polymer Analysis and Evaluation	PST	4	0	0	4	4	50	50	100	3
7	PT57L	Polymer Preparation Lab	PST	0	0	1.5	1.5	3	50	00	50	-
8	PT58L	Processing Technology Lab	PST	0	0	1.5	1.5	3	50	00	50	-
Total							27.0	30	-		700	-

SRI JAYACHAMARAJENDRA COLLEGE OF ENGINEERING (SJCE), MYSURU 570006

Scheme of Teaching and Examination for B.E (Polymer Science and Technology)

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Scheme 2014-18: OUTCOME BASED CURRICULLUM

SEMESTER VI

Sl. No.	Subject code	Course title	Teaching department	Credits				Contact hours per week	Marks			Exam duration in hours
				L	T	P	Total		CIE	SEE	Total	
1	PT610	Testing of Polymers	PST	4	0	0	4	4	50	50	100	3
2	PT620	Polymer Blends and Alloys	PST	4	0	0	4	4	50	50	100	3
3	PT630	Polymer Composites	PST	4	0	0	4	4	50	50	100	3
4	PT640	Processing Technology-II	PST	4	0	0	4	4	50	50	100	3
5	PT650	Product Design	PST	4	0	0	4	4	50	50	100	3
6	PT66X	Elective-1 (One from Group-1)	PST	4	0	0	4	4	50	50	100	3
7	PT67L	Polymer Analysis and Characterization Lab	PST	0	0	1.5	1.5	3	50	00	50	-
8	PT68L	Polymer Testing Lab	PST	0	0	1.5	1.5	3	50	00	50	-
Total							27.0	30	-		700	-

Courses offered in Elective Group-1 (One subject of this to be taken)		
Sl. No.	Subject code	Course title
1	PT661	Nanotechnology
2	PT662	Engineering Plastics
3	PT663	Fiber Technology
4	PT664	Modeling and Simulation

Sl. No.	Subject code	Course title	Teaching department	Credits				Contact hours	Marks			Exam duration in hours
				L	T	P	Total		CIE	SEE	Total	
5	G16PS 01	Graphene-based nano-composites for Energy Harvesting/ Storage Applications	PST	2	0	0	2	25	25	25	50	1.5

SRI JAYACHAMARAJENDRA COLLEGE OF ENGINEERING (SJCE), MYSURU 570006

Scheme of Teaching and Examination for B.E (Polymer Science and Technology)

Scheme revised in 2015

Scheme 2014-18: OUTCOME BASED CURRICULLUM

SEMESTER VII

Sl. No.	Subject code	Course title	Teaching department	Credits				Contact hours per week	Marks			Exam duration in hours
				L	T	P	Total		CIE	SEE	Total	
1	PT710	Rubber Products Manufacturing	PST	4	0	0	4	4	50	50	100	3
2	PT720	Polymer Recycling	PST	4	0	0	4	4	50	50	100	3
3	PT730	Design of Moulds and Dies	PST	3	1	0	4	5	50	50	100	3
4	PT74X	Elective-2 (One from Group-2)	PST	4	0	0	4	4	50	50	100	3
5	PT75L	CAD Lab	PST	0	0	1.5	1.5	3	50	00	50	-
6	PT76P	Research Methodology	PST	2.5	0	0	2.5	2	50	-	50	-
Total							20.0	22	-		500	-

Courses offered in Elective Group-2 (One subject of this to be taken)		
Sl. No.	Subject code	Course title
1	PT741	Total Quality Management
2	PT742	Adhesives Technology
3	PT743	Packaging Technology
4	PT744	PVC Technology

SRI JAYACHAMARAJENDRA COLLEGE OF ENGINEERING (SJCE), MYSURU 570006

Scheme of Teaching and Examination for B.E (Polymer Science and Technology)

Scheme revised in 2015

Scheme 2014-18: OUTCOME BASED CURRICULLUM

SEMESTER VIII

Sl. No.	Subject code	Course title	Teaching department	Credits				Contact hours per week	Marks			Exam duration in hours
				L	T	P	Total		CIE	SEE	Total	
1	PT810	Industrial Engineering and Management	PST	4	0	0	4	4	50	50	100	3
2	PT82X	Elective-3 (One from Group-3)	PST	4	0	0	4	4	50	50	100	3
3	PT83X	Elective-4 (One from Group-4)	PST	4	0	0	4	4	50	50	100	3
4	PT84P	Project Work	PST	0	0	10.0	10.0	20	70	30	100	3
Total							22.0	32	-		400	12

Courses offered in Elective Group-3 (One subject of this to be taken):			Courses offered in Elective Group-4 (One subject of this to be taken):		
Sl. No.	Subject code	Course title	Sl. No.	Subject code	Course title
1	PT821	Paints Technology	1	PT831	Tire Technology
2	PT822	Biomaterials	2	PT832	ThermoPlastic Elastomers
3	PT823	Membrane Technology	3	PT833	Operations Research
4	PT824	Smart Materials			

Sl. No.	Subject code	Course title	Teaching department	Credits				Contact hours per week	Marks			Exam duration in hours
				L	T	P	Total		CIE	SEE	Total	
5	GE01 PS	Functional Polymeric Materials	PST	2	0	0	2	2	25	25	50	1.5

III Semester

MA310B: ENGINEERING MATHEMATICS–III (NUMERICAL METHODS) (4-0-0)

Course Objective: Computational techniques will be introduced in different topics like algebra, calculus, linear algebra.

Course Outcomes: Students will be able to-

CO1: Understand how machine computation is done and the error analysis arising out of this;

CO2: Interpolate the given data using appropriate techniques;

CO3: Obtain values of various functions arising out of engineering problems using appropriate techniques;

CO4: Handle matrix computations that come up in linear algebra like accurate / approximate solutions of systems of linear equations, eigen values, eigenvectors, inverses, etc.;

CO5: Make differential and integral calculus related computations to determine physical quantities like area, volume, velocity, acceleration, etc., and numerically solve differential equations;

Course Content:

1	**Number representation on the computer:** floating point arithmetic; machine precision and errors – truncation errors and round-off errors; random number generation.	**6h**
2	**Curve fitting:** Newton / Lagrange interpolation techniques, difference formulas, Bezier curves.	**6h**
3	**Root finding:** bisection method, method of false-position, Newton-Raphson's method, roots of polynomials.	**6h**
4	**Linear system of equations:** Eigen values and eigenvectors; Cayley-Hamilton theorem; LU-factorization, Gauss-Jordan elimination, Gaussian elimination; iterative methods, Jacobi's method, Gauss-Seidel method; eigen values by power method; finding inverses of matrices; application to search engines.	**10h**
5	**Numerical differentiation and integration:** computing first and second derivatives, Richardson extrapolation; Newton-Cotes integration formulas, Trapezoidal rules,	**12h**

	Simpson's rules; Gauss quadrature; Romberg integration; numerical methods of solving differential equations.	

Text Books:

1. Schilling, R. J.; Harris, S. L. **Applied numerical methods for engineers,** Pacific Grove, CA, 2000.
2. Kreyszig, E. **Advanced engineering mathematics;** 3d ed.; Wiley: New York, 1972.

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PT310: INORGANIC AND PHYSICAL CHEMISTRY (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Discuss the fundamentals of inorganic chemistry and inorganic polymers	
CO2:	Explain the basic concepts of coordination compounds	
CO3:	Determine the colligative properties and their applications	
CO4:	Explain catalysis and chemical equilibrium	
CO5:	Apply polymer colloidal solution and adsorption behavior knowledge to select suitable material for various end-use applications	
Course Content:		
Unit 1	**Introduction:** basics of inorganic chemistry, overview of periodic table, classification and types of inorganic compounds, uses of inorganic molecules in polymer engineering. **Inorganic Polymers:** Definition of inorganic polymers, comparison of organic polymers with inorganic polymers, A critical account (in brief) of preparation, properties, structure and applications of phosphonitrillic, silicon based, carbide, borohydride, borazine, iso- and hetero- poly acid classes of inorganic polymers.	**10h**
Unit 2	**Coordination compounds:** Definitions and terminologies- double salts, coordination compounds, coordination complexes, chelates, coordination numbers, ligands, chelating ligands and chelates. Nomenclature of coordination compounds. Physical methods in the study of complexes. Theories of Coordination complexes (Crystal field theory, Valence bond theory and molecular orbital theory Postulates and drawbacks of these theories). Stability of complex ions, stability constants, factors affecting the stability of a complex ion, stereo-regularity of coordination compounds with different coordination numbers, Isomerism, isomerism in coordination compounds, structural isomerism, coordination isomerism, coordination position isomerism, stereo isomerism, geometrical isomerism and optical isomerism.	**10h**
Unit 3	**Colligative Properties:** Definition and types; concept of mole and mole fraction, Lowering of vapor pressure, Raoult's law– statement, limitation, determination of	**10h**

	molecular weight, Ostwald's and Walker's method. Osmosis and osmotic pressure– explanation of the terms, effect of temperature and concentration and simultaneous effect; derivation of molecular weight, Berkeley and Hartely's method, isotonic solutions– explanation, molecular weight determination. Elevation in boiling point of a solvent– derivation, experimental determination of molecular weight by ebullioscopic method; Depression in freezing point, experimental determination of molecular weight by cryoscopic method, numerical problems.	
Unit 4	**Catalysis:** Types with examples of catalytic reactions, homogeneous and heterogeneous, theory and mechanism of catalytic reactions, characteristics of catalytic reactions, negative catalysts, enzyme catalysts, acid-base catalysts. Zeigler Natta (coordination) catalysts, inorganic catalysts (like Zeolites, Silicates) and their applications. **Chemical Equilibrium:** Spontaneous reactions, standard free energy change, Characteristics of chemical equilibrium, effects of temperature on equilibrium constant. Application of law of mass action. Equilibrium of ideal solutions. Thermodynamic treatment of the law of mass action, The Van't Hoff reaction isotherm, relation between K_p, K_c and K_x; numerical problems.	**10h**
Unit 5	**The Colloidal State–** Colloidal systems, classification of colloids, lyophobic and lyophillic sols, preparation of lyophobic colloidal solutions, purification of colloidal solutions, properties of colloidal systems, electrical and electro-kinetic properties, determination of size of colloidal particles. **Adsorption:** Definition, types of adsorption: chemisorption & physisorption; influence of temperature and pressure, nature of adsorbent and adsorbed gas, Freundlich's adsorption isotherm, unimolecular layers, Longmuir's adsorption isotherms (derivation of equation), and numerical problems	**10h**

Text books:

1. B.R.Puri, L.R.Sharma and K.C. Kalia, Principles of Inorganic Chemistry, Milestone Publishers & Distributors, New Delhi, 2008.

2. B.R.Puri, L.R.Sharma, and Pathania, Principles of Physical Chemistry, 46th Ed., Vishal Publication & Co., New Delhi, 2013. Author. Title, edition, Publisher, Place, Year.

References:

1. Okhil K. Medhi, Ellen A. K., James E. Huheey, Richard L. Keiter, Inorganic Chemistry: Principles of Structure and Reactivity, 4th Edition, Pearson, India, 2006.
2. Gary L. Miessler, Donald A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson, India, 2008.
3. Shriver, Ed. by Peter Atkins, Inorganic Chemistry, 8th edition, Oxford Pub, UK, 2009.
4. Gurdeep Raj, Goel, Advanced Inorganic Chemistry, Vol. I, II; Publishing House, Meerut, India, 2011.
5. Philip Mattews, Advanced Chemistry, 1st Edition, Cambridge University Press, New Delhi, 2008.
6. Samuel Glasstone, Text book of Physical Chemistry, 2nd Ed., Macmillan India Press, Madras, 1984.

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PT320: ORGANIC CHEMISTRY (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Understand and Explain fundamentals of organic chemistry;	
CO2:	Explain the nomenclature, reactions, properties & applications of acyclic and carbocyclic hydrocarbons;	
CO3:	Explain the nomenclature, reactions, properties & applications of aromatic/ heterocyclic/ hydroxyl/ halogenated hydrocarbons;	
CO4:	Explain the nomenclature, reactions, properties & applications of amino/ carboxylic hydrocarbons; and explain the fundamentals of selected organic families;	
CO5:	Illustrate the synthesis reactions of monomers.	
Course Content: [Note: • Preparation or synthesis implies brief study of important chemical reactions yielding the organic compounds. • Under properties and applications, only the important ones and those applicable to polymer technology is to be discussed. • Fundamentals imply structure, classification, nomenclature and important characteristics. • Under each topic, the names and chemical structures of organic molecules are to be used as examples, compulsorily.]		
Unit 1	**Introduction and Structure:** Definition of organic compounds; Classification based on structure and chemical family. IUPAC Nomenclature of organic compounds (general). Bonding in organic molecules: ethane, ethylene, acetylene and butadiene. Electron displacement effect (inductive, mesomeric, inductomeric, electromeric, hyper-conjugation and resonance effects); Polarity of bonds. **Basics of Polymer Technology-** Definitions of basic terminologies: organic polymers, functionality, polymerization, copolymer, polymer blend, polymer composite, polymer compound. Comparison between simple molecules, monomers and macro-molecules. Overview of polymer applications. Scope of organic	**10h**

	chemistry in polymer technology. **Reactivity and Mechanism:** Reactions- types and characteristics; homolysis and heterolysis (concept of ions and radicals); addition, substitution, elimination and rearrangement (general conditions and mechanism); introduction to other types of reactions. Types of reagents– electrophiles and neucleophiles; Acids and bases: types and strengths. **Stereochemistry-** stereo isomerism (optical and geometrical). Bayers strain theory, Sasche and Mohrs theory, concept of conformation analysis with respect to ethane, ethylene di chloride and cyclohexane.	
Unit 2	**Study of organic families:** definition, types, chemical structure, nomenclature, synthesis approach, reactivity, properties & applications of each of the following class of organic molecules is to be discussed along with some characteristic reactions as mentioned- **i) Acyclic hydrocarbons: Alkanes-** relative reactivity of higher alkanes with halogens. **Alkenes-** electrophyllic addition reactions with halogens, Markownikoff's rule, alkylation and polymerization. Addition of halogens to dienes, Diels Alder's reactions. **Alkynes-** Acidity and polymerization of alkynes. **ii) Carbocyclic hydrocarbons: Alicyclic compounds:** cyclo-alkanes, cyclo-alkenes, and cyclo-alkynes. Brief introduction to polycyclic hydrocarbons (e.g. cyclopentene, DCPD, norbornene, etc).	**10h**
Unit 3	**iii) Aromatic compounds:** aromaticity, resonance energy and substitution reaction. **iv) Heterocyclic organic compounds**: Brief study including saturated, unsaturated and aromatic types (e.g. oxirane, furan, thiophene, pyrrole, pyridine, thiazine, etc.) **v) Halogenated hydrocarbons.** **vi) Hydroxy compounds: Alcohols-** polyol**; & Phenols-** effect of substitution on acidity of phenols.	**10h**
Unit 4	**vii) Carboxylic acids**: Types (Dicarboxylic, Aromatic, Hydroxy, Amino acids, etc); Derivatives of acids; acidity and structure of carboxylic ions. Effect of	**10h**

	substitution on acidity; effect of heat on hydroxy acids. **viii) Amines.** **ix) Brief introduction to:** Aldehydes, Amides, Anilides, Anhydrides, Carbohydrates, Ethers, Esters, Ketones, Nitrile compounds, Nitro compounds and Urethanes.	
Unit 5	**Synthesis of:** ethylene, propylene, butadiene, isoprene, acetylene, benzene, styrene, tetrafluoroethylene, vinyl chloride, epichlorohydrin, acrylic acid, adipic acid, maleic acid, phthalic acid, lactic acid, hexamethylene diamine, aniline, melamine, phthalic anhydride, maleic anhydride, ethylene glycol, phenol, bisphenol-A, urea, acrylonitrile, caprolactam, caprolactone, formaldehyde, methylmethacrylate, vinyl acetate.	**10h**
Text book: Bahl B S, Text Book of Organic Chemistry, 9th ed, S Chand & Co, Delhi, 1967.		

References:

1. Morrison, R. T.; Boyd, R. N. Organic chemistry; 3d ed.; Allyn and Bacon: Boston, 1973.
2. Weissermel, K.; Arpe, H. Industrial organic chemistry: important raw materials and intermediates; 1. Aufl.; Verlag Chemie: Weinheim, 1978.
3. Jain, M. K. Principles of organic chemistry; 8th rev.; Nagiu: Jullundar, 1976.
4. Sykes, P. A guidebook to mechanism in organic chemistry; 6th ed.; Longman: Harlow, Essex, England, 1986.
5. Finar, I. L. Organic chemistry, 6th ed.; Longman: London, 1973.
6. Lloyd N. Ferguson, The Modern Structural Theory Of Organic Chemistry, Prentice Hall. 1962.
7. Waddams, A. L. Chemicals from petroleum: an introductory survey; 3d ed.; Wiley: New York, 1973

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PT330: POLYMER CHEMISTRY (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain fundamentals of polymer chemistry and classification of polymers	
CO2:	Explain mechanism for polymerization reactions	
CO3:	Explain polymerization methods with importance	
CO4:	Explain the fundamentals of copolymerization and special topics in polymer synthesis	
CO5:	Outline the important polymer reactions and purification of polymers.	
Course Content:		
Unit 1	**Introduction and Nomenclature:** Functionality of monomers and its role in deciding polymers' structure (linear, branched and cross-linked); Review of basics of polymer technology. IUPAC names, trade or commercial names, source based and structure based names of various polymers. Abbreviations and grades of polymers. General remarks on form or physical nature of polymeric materials- plastics, rubbers, fibers/textiles, latex/emulsions, resins. **Classifications of polymers:** [brief description of each classification; names and chemical structures of polymers to be discussed in each type of classifications covering around seventy well known polymers]: On the basis of source (natural, synthetic & semi-synthetic); backbone composition (organic & inorganic polymer; homo & co-polymer; homo-chain & hetero-chain polymer); polymerization (addition & condensation); effect of heat (thermo-plastic polymers & thermo-setting polymers); geometric isomerism (cis & trans polymers) and stereo isomerism (tacticity- iso, syndio & atactic polymers); application (commodity, engineering & high-performance); molecular structure (linear, branched & cross-linked); microstructure (amorphous, crystalline & semi-crystalline). **Polymerization:** Difference between addition/chain & condensation/ step polymerization; Raw materials used in polymerization: Discussion about role & examples of- initiator, inhibitor, retarder, chain transfer agent, catalyst, short-stop, and medium; Factors affecting polymerization.	**10h**
Unit 2	**Chemistry of Polymerization**	**10h**

	Chain (addition/vinyl) polymerization: Definition & types. Addition polymerization (reaction and/or mechanism) - free radical, anionic and cationic- Initiation, propagation, and termination by different approaches under each technique has to be discussed along with examples of polymers produced and highlights of each technique. **Step (condensation) polymerization:** Definition & types. Condensation polymerization reaction and/or mechanism (polyesters (PET & PBT), polyamides (nylon 6 and nylon 66), polyethers, phenol-formaldehyde. Poly-addition reaction (polyurethane, polyurea). **Stereo regular (Co-ordination) polymerization:** Types and structures of initiators (Zeigler-Natta catalyst and other types), Polymerization mechanism, advantages & disadvantages, types and examples of stereo specific polymers with applications	
Unit 3	**Copolymerization:** definition of co-monomers & co-polymers; classification based on process and repeat units; need of copolymerization with specific examples; free radical copolymerization and its mechanism; ionic copolymerization and its mechanism **Special topics in polymer synthesis-** Polyaddition**,** polymerization, metathesis polymerization, interfacial condensation, electrochemical polymerization, group-transfer polymerization, [brief and general mechanism or method, important polymers produced, advantages/ specialty and disadvantages/ limitations of each technique to be highlighted].	**10h**
Unit 4	**Methods of Polymerization:** Bulk, solution, suspension, emulsion, solid phase, gas phase, ring opening, melt condensation, solution condensation and plasma polymerization (mechanism, important polymers produced, properties of the polymer produced, advantages and limitations of each technique to be discussed).	**10h**
Unit 5	**Polymer reactions:** introduction; types- hydrolysis, acidolysis, addition, substitution, halogenation, hydrogenation, crosslinking, curing, (brief mechanism and usefulness of each reaction to be highlighted with examples). **Isolation and purification of polymers:** Need of isolation and purification; polymer fractionation, fractional precipitation and partial dissolution (extraction)	**10h**

	technique.	

Text books:

1. Padma L Nayak, Polymer Science, Kalyani Publishers, New Delhi, 1st Edn, 2005.
2. Gowariker, V. R.; Viswanathan, N. V., Polymer Science; Wiley: New York, 1986.

References:

1. Rodriguez, F. Principles of polymer systems; McGraw-Hill: New York, 1970.
2. Seymour, R. B.; Carraher, Polymer chemistry: an introduction; 4th ed.; M. Dekker: New York, 1996.
3. Odian, G. G. Principles of polymerization; Fourth ed, Wiley, 2004.
4. Young, R. J and P.A.Lovell, Introduction to polymers; Chapman and Hall: London, 1981.
5. Anil Kumar, Fundamentals Of Polymer Science and Engineering, Tata McGraw Hill, New Delhi, 1978
6. G.S. Misra, Polymer Chemistry, Wiley Eastern Ltd., New Delhi, 1993
7. Billmeyer Fred W. JR. Textbook of polymer science, John Wiley & Sons, New York, 1984

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PT340: THERMODYNAMICS (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain first law of thermodynamics and its applications	
CO2:	Derive and apply second law of thermodynamics	
CO3:	Estimate the thermodynamic properties of fluids using the concept of Gibbs free energy, Helmholtz free energy and Maxwell equations.	
CO4:	Apply the concepts of chemical potential and partial properties in binary solutions.	
CO5:	Apply thermodynamic principles in polymer solutions and elastomers.	
Course Content:		
Unit 1	**Introduction & I Law of Thermodynamics**: Thermodynamic terms, first law of thermodynamic, statement, mathematical expression, the equivalence of heat and work, heat-a path function, work- a path function, internal energy (E), work, heat and energy changes, pressure of work, heat content (enthalpy), heat capacities at constant volume and constant pressure, heat capacity relationships; the internal energy of an ideal gas, isothermal process, adiabatic processes, isochoric process, isobaric process, numerical problems.	**10h**
Unit 2	**II Law of Thermodynamics:** work and expansion in reversible adiabatic process Spontaneous processes, II law of Thermodynamics; statement, the Carnot cycle for a gas and Elastomers, work and efficiency, entropy, entropy changes of an ideal gas; entropy change in a reversible process, entropy change in an irreversible process, entropy and the II law , numerical problems.	**10h**
Unit 3	**Thermodynamic properties of fluids:** Property relations for homogeneous phases – Maxwell's relations, H and S as functions of T and P, U as a function of P, alternative forms for liquids, U and S as functions of T and V of residual properties, , numerical problems.	**10h**
Unit 4	**Solution thermodynamics:** Fundamental property relations- the chemical potential and phase equilibrium, partial properties, Gibbs-Duhem equation, partial properties in binary solutions, numerical problems.	**10h**
Unit 5	**Thermodynamics of polymer solutions and elastomers:** thermodynamics of	**10h**

	ideal solutions, Flory Huggin's theory, partial molar quantities and chemical potential, dilute polymer solutions, the solubility parameter approach, Phase separation behavior of polymer solutions. Elastic deformation, thermoelastic inversion effect, numerical problems.	

Text books:

1. J.M.Smith and H.C.Van Ness. Introduction to Chemical Engineering thermodynamics; Mc.Graw Hill, New Delhi.1987.
2. R.J.Young & P.A. Lovell, Introduction to Polymers; Chapman & Hall; London, 1992.

References:

1. L.H.Sperling, Introduction to Physical polymer science; John Wiley and Sons; London, 1985
2. A.Tager, Physical chemistry of Polymers; Mir publishers; Moscow, 1978.
3. Joel. R.Fried, Polymer Science & Technology; Prentice Hall India Private Limited; New Delhi, 1995.
4. Narayanan K.V. Textbook of Chemical Engg. Thermodynamics, Prentice Hall India Private Limited, New Delhi, 2001.

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PT350: TRANSPORT PHENOMENA IN MATERIALS ENGINEERING-I (4-0-0)		
Course Outcomes: Upon successful completion of this course, the students will be able to-		
CO1:	Explain the fundamentals of fluid mechanics and concepts of dimensional analysis.	
CO2:	Explain concepts of laminar and turbulent flow.	
CO3:	Apply the concepts of mass, momentum and mechanical energy balance.	
CO4:	Explain principles of various fluid flow measuring devices and basic concepts of chemical process calculation.	
CO5:	Perform material balance with chemical reaction and can apply the knowledge for problem solving.	
Course Content:		
Unit 1	**Engineering Units and Pressure in Static Fluids:** Basic Engineering Units, Concept of Pressure, Pascal's law, Measurement of Pressure, numerical problems. **Dimensional Analysis:** Step by step procedure for dimensional analysis, Buckingham's' Π theorem, example problems on dimensional analysis. Dimension less groups and their importance.	**10h**
Unit 2	**Momentum Transport and Laminar Flow of Newtonian Fluids**: Introduction, Newton's Law of Viscosity, Conservation of Momentum in Steady-State Flow, Fluid Flow in a horizontal and Vertical Cylindrical pipes, Fluid Flow in an Annulus, Fluid Flow Between Two Flat Parallel Plates, Capillary Flow meter, numerical problems. **Turbulent Flow:** Introduction, Friction Factor and Turbulent Flow in Cylindrical Pipes, Flow Through Packed Beds and Fluidized Beds, numerical problems.	**10h**
Unit 3	**Mechanical Energy Balance and Its Application to Fluid Flow:** Introduction, Bernoulli's Equation, Frictional Loss, Influence of Bends, Fittings and Changes in the Pipe Radius, Concept of Head, Bernoulli's Equation for Flow of Compressible Fluids. Numericals.	**10h**
Unit 4	**Flow measuring devices:** Pitot Tube, Orifice meter, Venturi meter, numericals. **Chemical process calculations, material balance without reaction:** General	**10h**

	material balance equation for steady and unsteady state. Process calculations, Typical steady state material balances in distillation, absorption, extraction, crystallization, mixing and evaporation, numerical problems.	
Unit 5	**Steady state material balance with reaction:** Principles of Stoichiometry, Concept of limiting, Excess reactants and inerts, Fractional and percentage conversion, Fractional and percentage yield, Selectivity, numerical problems.	**10h**

Text books:

1. David R Gaskell. An Introduction to Transport Phenomena in Materials Engineering, 2nd Edition, Momentum press, LLC, New Jersey, 2012.
2. R K Bansal. A Textbook of Fluid Mechanics. 3rd edition, Laxmi publications (P) Ltd, New Delhi, 2005.

References:

1. Hougen O.A., Watson K.M. and Ragatz R.A. Chemical Process Principles, Part–I Material and Energy Balances, 2nd edition, CBS publishers and distributors, New Delhi, 1995.
2. Himmelblau, D.M. Basic Principles and calculations in Chemical Engineering, 6th Edn, Prentice Hall of India, New Delhi, 1997.
3. Poirier D. R., and Geiger G. H. Transport Phenomena in Materials Processing, Wiley Publications, 1998.
4. McCabe W.L. and Smith. Unit Operations of chemical Engineering, 6th edn., McGraw Hill Publications, New York , 2001.

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PT36L: ORGANIC CHEMISTRY LAB (0-0-1.5)

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

CO1:	Explain the fundamentals, procedure and significance of organic chemistry experiments;
CO2:	Conduct experiments by adopting laboratory disciplines;
CO3:	Identify organic compounds by qualitative analysis;
CO4:	Synthesize or Quantitatively Analyze some important organic compounds;
CO5:	Analyze, interpret and report the experimental data suitably.

List of experiments:

Part - A	**Part - B**
Identification of organic compounds of the following types: 1. Hydrocarbons 2. Alcohols 3. Esters 4. Aldehydes 5. Ketones 6. Carboxylic acids 7. Amines 8. Amides 9. Carbohydrates 10. Nitro compounds 11. Halogen compounds 12. Phenols 13. Anilides	**I. Single step preparation of organic compounds by the following methods.** 1. Nitration 2. Acetylation 3. Bromination 4. Oxidation 5. Hydrolysis **II. Qualitative estimation of** 1. Aniline 2. Phenol 3. Acetone 4. Acetamide 5. Ethyl or Methyl acetate

Text book: Vogel A I. Elementary practical organic chemistry**,** 2nd ed, Wiley, New York, 1966.

References:

1. Bahl B S. Text Book of Organic Chemistry, 9th ed, S Chand & Co, Delhi, 1967.
2. Organic Chemistry Lab Manual (Department of PST).

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PT37L: FLUID MECHANICS LAB (0-0-1.5)

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

CO1:	Interpret the nature of flow and understand concept of flow through fluidized and packed bed.
CO2:	Practically determine hydraulic coefficients and pressure drops.
CO3:	Compare the efficiencies of various flow measuring devices.
CO4:	Experimentally determine minor and major energy losses in pipe flow.
CO5:	Construct performance characteristic curves for single and multi stage centrifugal pump.

Course Content: List of experiments

1. Determination of Reynolds number
2. Determination of Hydraulic coefficients using a vertical orifice (circular) discharging fluid freely into atmosphere
3. Calibration of Venturimeter
4. Calibration of Orifice meter
5. Calibration of Rectangular and V-Notch
6. Determination of Darcy's friction factor for pipes of uniform diameter
7. Minor Losses in pipes: Determination of minor losses of head in pipes due to (i) Sudden expansion (ii) Sudden contraction and (iii) Bends and Elbows
8. Determination of hydraulic coefficients for different types of mouth pieces.
9. Flow through fluidized bed
10. Flow through packed bed
11. Experiments to determine the characteristics of a Single stage centrifugal pump
12. Experiments to determine the characteristics of a Multi-stage centrifugal pump**.**

Text books:

1. R K Bansal. A Textbook of Fluid Mechanics. First edition, Laxmi publications (P) Ltd, New Delhi, 2005**.**

References:

1. McCabe, W.L., Smith J C and Harriot P. Unit Operations of chemical Engineering, 6th edn., McGraw Hill Publications, New York , 2001.
2. Coulson J.M. and Richardson .J.F., Chemical Engineering, Vol. 1, 6th edn., Butterworth Heinemann, Oxford, 2002.
3. David R Gaskell. An Introduction to Transport Phenomena in Materials Engineering, 2nd Edition, Momentum press, LLC, New Jersey, 2012.

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HU310: CONSTITUITION OF INDIA AND PROFESSIONAL ETHICS (2-0-0)

Course Objectives:

- The objective of studying the Constitution of India is to increase the legal and social awareness of the engineers so that they are equipped to face challenges they may confront in their careers and also to encourage them to actively participate in the political process of the country.
- The objective of studying professional ethics is to equip an engineer to face such situations and to solve such conflicts in compliance with the accepted ethical principles and norms.

Course Outcomes: After the completion of the course the student will-

CO1: Have knowledge about and an understanding of constitutionally guaranteed rights and duties of every citizen. Have knowledge about the various forums that actively participate in protecting these rights in case of violation.

CO2: Have an understanding of the working of the electoral process, amendment procedure. Have an understanding of the different organs of the State, namely legislature, executive and the judiciary.

CO3: Have an understanding of the powers & functions of state legislature and Union legislature. Have an understanding of the powers & functions of state executive, and Union executive and emergency provisions.

CO4: Have an understanding of the special provisions related to SCs, STs, Women, children and backward classes. Have an understanding of the scope, limitation and functioning of the Indian judiciary. Have an understanding of the importance of fundamental duties and directive principles of state policy.

CO5: Be able to develop the ethical autonomy i.e., the skill and the habit of thinking rationally and critically about the ethical values viz honesty, integrity and reliability. Be able to build and contribute to a safe and healthy work environment. Be able to better serve in responsible positions of leadership and discharge his duties better.

CO6: Be equipped with better decision making abilities and will be able to make morally and ethically sound decisions. Be able to make positive contribution to the society. Be

examples of faith, character, and high professional ethics.

Course Content:

1. Preamble to the constitution of India. Fundamental Rights under Part III - details of Exercise of rights, Limitations and Important cases.
2. Relevance of Directive Principles of State Policy under Part IV. Fundamental duties and their significance.
3. Union Executive - President, Prime Minister, Parliament and the Supreme Court of India.
4. State executive - Governors, Chief Minister, State Legislator and High Courts.
5. Constitutional Provisions for Scheduled Castes and Tribes, Women & Children & Backward classes, Emergency Provisions.
6. Electoral process, Amendment procedure, 42nd, 44th, 74th, 76th, 86th and 91st Constitutional amendments.
7. Scope & aims of engineering Ethics, Responsibility of engineers. Impediments to responsibility.
8. Honesty, Integrity and reliability, risks, safety & liability on engineering.

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IV Semester

MA310A/MA410A: ENGINEERING MATHEMATICS–IV

(Fourier Series, Integral Transforms And Applications) (4-0-0)

Course Objective:

- Fourier series and Integral transforms techniques will be introduced.
- Applications of Integral transforms to solution of differential equations will be discussed. Elementary Complex analysis is introduced.

Course Outcomes: Students will be able to-

CO1: Find expansions of functions as Fourier series / half-range Fourier series in a given range of values of the variable. Obtain the various harmonics of the Fourier series expansion for the given numerical data.

CO2: To find Fourier transforms, Fourier sine and Fourier cosine transforms of functions.

CO3: Use Laplace transforms to determine solutions to linear differential equations.

CO4: Solve difference equations using Z-transforms.

CO5: Analyze functions of complex variable and handle analytic functions.

CO6: Apply Cauchy-Riemann equations and harmonic functions to problems of Fluid Mechanics, Thermo Dynamics and Electromagnetic fields.

CO7: Geometrically interpret conformal and bilinear transformations.

Course Content:

1	**Fourier series:** Introduction, Fourier series for even and odd functions; half-range expansions; practical harmonic analysis.	**6h**
2	**Fourier transforms:** Fourier transforms, inverse transforms, applications to ordinary and partial differential equations; discrete Fourier transforms.	**6h**
3	**Laplace transforms and inverse Laplace transforms:** applications to differential equations.	**12h**
4	**Linear Algebra:** Real vector spaces; linear dependence/independence; basis / dimension; linear transformations; rank – nullity theorem.	**10h**

5	**Z-transforms:** z-transforms and inverse z-transforms; solution of difference equations.	**6h**
6	**Complex Analysis:** Introduction, analytic functions; C-R equations; properties of analytic functions; construction of conformal mappings.	**8h**
Text Book: Kreyszig, E. **Advanced engineering mathematics;** 3d ed.; Wiley: New York, 1972.		

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PT410: MATERIAL SCIENCE AND ENGINEERING (4:0:0)		
Course Outcomes: Upon successful completion of this course, the students will be able to		
CO1:	Analyze material atomic structure and bonding.	
CO2:	Modify material properties for an engineering application and construct the phase diagrams for given material systems.	
CO3:	Explain composite, ceramic properties and applications.	
CO4:	Explain electrical and mechanical properties of materials.	
CO5:	Explain properties and applications of advanced materials.	
Course Content:		
Unit 1	**Structure:** Atomic structure and bonding in materials. Crystal structure of materials, crystal systems, unit cells and space lattices, determination of structures of simple crystals by x-ray diffraction, miller indices of planes and directions, packing geometry in metallic, ionic and covalent solids. Concept of amorphous, single and polycrystalline structures and their effect on properties of materials. Crystal growth techniques. Imperfections in crystalline solids and their role in influencing various properties, numerical problems.	**10h**
Unit 2	**Metals and Alloys:** Solid solutions, solubility limit, the phase rule, the lever rule, single component systems, binary phase diagrams, intermediate phases, iron-iron carbide phase diagram, heat treatment of steels, cold and hot working of metals, recovery, re-crystallization and grain growth, micro-structural changes during cooling. Microstructure, properties and applications of ferrous and non-ferrous alloys. Applications of phase diagrams, numerical problems.	**10h**
Unit 3	**Composites:** Properties and applications of various composites. **Ceramics:** Structure, properties, processing and applications of traditional and advanced ceramics. **Mechanical Properties:** stress-strain diagrams of metallic, ceramic and polymeric materials, modulus of elasticity, yield strength, tensile strength, toughness, elongation, plastic deformation, visco-elasticity, hardness, impact strength, creep, fatigue, ductile and brittle fracture, numerical problems.	**10h**

Unit 4	**Magnetic Properties:** Origin of magnetism in metallic and ceramic materials, para-magnetism, diamagnetism, ferromagnetism, anti-ferromagnetism, ferrimagnetism, magnetic hysteresis. Numerical problems. **Electrical Properties:** Concept of energy band diagram for materials – conductors, semiconductors and insulators, electrical conductivity – effect of temperature on conductivity, intrinsic and extrinsic semiconductors, dielectric properties. Numerical problems.	**10h**
Unit 5	**Advanced Materials:** Smart materials, materials exhibiting ferroelectric, piezoelectric, opto-electric, semiconducting behavior, lasers and optical fibers, photoconductivity and superconductivity, nano-materials – synthesis, properties and applications, biomaterials, superalloys, shape memory alloys.	**10h**

Text books:

1. V Raghavan. Materials Science & Engineering, 5th Edition, PHI Learning Pvt. Ltd., New Delhi, 2011.
2. R. Balasubramaniam. Callister's Materials Science and Engineering, 2nd Edition, Wiley India Pvt. Ltd. New Delhi, 2014.

References:

1. William D Callister. Materials Science and Engineering, John Wiley, New York, 2007.
2. A.K. Bhargava. Engineering Materials, Prentice-Hall of India Pvt. Ltd., 2005.
3. L.H. Van Vlack. Elements of Material Science & Engineering, 6th edition, Addison-Wesley Publishing Co., New York, 1989.

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PT420: POLYMER PHYSICS (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain basic concepts of micro structure of polymers.	
CO2:	Explain the fundamental concepts of crystallization of polymers.	
CO3:	Explain the polymer thermal transition behavior.	
CO4:	Determine molecular weight of polymers using different experimental techniques and equations.	
CO5:	Apply the concepts of polymer solution in designing products such as colloidal dispersions, hydrogels and solvent based adhesives	
Course Content:		
Unit 1	**Chain Configurations:** Conformation of polymers-constitutional isomerism, positional isomerism, branching; Configurational isomerism- geometrical isomerism, stereo isomerism; polymer conformation-conformation of small molecules and conformation of polymers; Conformation of macromolecules-General shape of macromolecules – general shape of macromolecules; definition of conformational parameters of a chain-end to end distance.	**10h**
Unit 2	**The Crystalline State:** Crystallizability, polymer crystallization (mechanism), factors affecting Crystallizability of polymer, Spherulites, methods used to determine crystallinity, effect of crystallinity on properties, melting behavior, factors affecting on T_m, Kinetics of Crystallization. Applications of Avrami equation, orientation crystallization and annealing. Crystal structure of polymers: Molecular aggregation, molecular arrangement in crystallites, polyethylene, syndiotactic Vinyl polymers, PTFE, PVA, polyesters, Polyamides, Polydienes; the principles of crystallite structure, Single crystals of polymers.	**10h**
Unit 3	**Methods of measuring molecular weight averages:** The concept of molecular weights (number average molecular weight, weight average molecular weight, viscosity average and z-average molecular weight – definition and mathematical expressions), molecular weight distribution and its importance and polydispersity. Methods of measuring molecular weight: Ebuilioscopy, Cryoscopy, membrane	**10h**

	osmometry, vapor pressure osmometry, end group analysis, light scattering, viscometry, and ultracentrifugation methods. (Principle, theory, experimental procedure, merits, demerits of each techniques and problems should be discussed).	
Unit 4	**Transition of polymers– from glassy to rubber like and viscofluid states:** Five regions of viscoelastic behavior; glassy region, glass transition region, rubbery flow region, rubbery plateau region, the liquid flow region, Relaxation nature of glass transition, mechanism of glass transition, methods of determining glass transition temperature – Dilatometry, thermal methods, mechanical methods, other transitions and relaxations; main chain and side chain motions, T_{LL} (liquid-liquid transition), Factors affecting $T_{g.}$	**10h**
Unit 5	**True solutions of polymers:** Specific properties of true solution, dissolution and swelling of polymers, degree and kinetics of swelling, polyelectrolytic solutions, factors affecting dissolution and swelling of polymers, gels of polymers, colloidal dispersions of polymers, preparation of polymer solutions and their refining, resistance of polymeric materials to solvents.	**10h**

Text book: Sperling, L. H. Introduction to physical polymer science; Wiley: New York, 1986.

References:

1. David I. Bower, An Introduction to Polymer Physics, Cambridge University Press, New York, 2002.
2. A.Tagar, Physical Chemistry of polymers, Sec. Edn, MIR Publishers, Prentice Hall Inc 1978.
3. V.N.Kuleznev & V.A. Shershnev, The chemistry and physics of polymer, Sec. Edn – MIR Publisher, Moscow, 1988
4. S. F. SUN St, Physical chemistry of macromolecules Basic Principles and Issues, Sec. Edn, Wiley-Interscience Publication, John Wiley & Sons Inc., New York, 2004.
5. Yves Gnanou, Michel Fontanille, Organic and physical chemistry of polymers, Wiley-Interscience Publication, John Wiley & Sons Inc New York, 2008.
6. Padma L Nayak, Polymer Science, Kalyani Publishers, New Delhi, 1st Edn, 2005.
7. Jerold Schutz, Polymer Material science, First Edn. Prentice Hall Inc, 1974.
8. Fried, J. R., Polymer science and technology, Prentice Hall PTR: Englewood Cliffs, N.J., 1995.

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PT430: POLYMER MANUFACTURING TECHNOLOGY (4-0-0)		
Course Outcomes: Upon successful completion of this course, the students will be able to explain-		
CO1:	Chemistry, manufacturing process, compounding ,properties and applications of polyolefin's	
CO2:	Chemistry, manufacturing process, compounding, properties and applications of styrene's and acrylics.	
CO3:	Chemistry, manufacturing process, compounding, properties and applications of PVC and engineering thermoplastics.	
CO4:	Chemistry, manufacturing process, compounding, properties and applications formaldehyde based thermosets.	
CO5:	Chemistry, manufacturing process, compounding, properties and applications of epoxy resin and urethane.	
Course Content:		
Unit 1	**Polyethylene**: HDPE, LDPE, LLDPE, VLDPE, UHMWPE, chlorinated PE (CPE), chloro sulphonated PE, copolymers of PE (EVA). **Polypropylene**: Isotactic, Syndio tactic and Atactic PP.	**10h**
Unit 2	**Polystyrene**: Polystyrene, HIPS & copolymers of styrene (SAN & ABS). **Acrylics:** PMA, PMMA, PAN **Polyvinyl chloride**	**10h**
Unit 3	**Polyamides**: Nylon 6 and Nylon 66 **Poly esters**: Thermoplastic (PET & PBT) **Poly carbonate**	**10h**
Unit 4	**Phenol formaldehyde. Urea formaldehyde. Melamine formaldehyde.**	**10h**
Unit 5	**Epoxy resins. Polyurethanes. Unsaturated Polyester resins.**	**10h**
Text book: Brydson, J. A. Plastics materials; Butterworth-Heinemann; 7 edition, Iliffe; London, 1966.		
References: 1. W. Mayo Smith, Manufacture of Plastics - Vol. I & II; Van Nostrand Reinhold; New York,		

1964

2. Irvin.I. Rubin, Hand Book of Plastics Materials & Technology**;** John Wiley & Sons Inc.; New York, 1990.

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PT440: POLYMERIZATION KINETICS (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Discuss the basic concepts of chemical kinetics	
CO2:	Explain kinetics of addition polymerization.	
CO3:	Derive kinetic expression for condensation polymerization.	
CO4:	Apply the kinetic aspects to derive kinetic expression for ionic & coordination polymerization	
CO5:	Derive kinetic equations for copolymerization and evaluate monomer reactivity ratio.	
Course Content:		
Unit 1	**General Chemical Kinetics:** Definition of reaction rate, order, molecularity, different theories of reaction rate - collision theory, transition state theory, Arrhenius law, activation energy, kinetic expressions for simple first order & second order chemical reaction. Different methods to determine order of reaction. Numerical problems.	**10h**
Unit 2	**Kinetics of addition polymerization:** Expressions for rate of initiator decomposition, chain initiation, chain termination, rate of propagation, steady state assumption, overall rate of polymerization, experimental approaches for determination of polymerization rate, Initiator efficiency, kinetic chain length, chain transfer, control of molecular weight by transfer, determination of individual rate constants by sector method. Numerical problems.	**10h**
Unit 3	**Kinetics of condensations polymerization:** Rate expression for acid catalyzed and non catalyzed reaction, statistics of linear step reaction polymerization, molecular weight control, principle of equal reactivity of functional groups. Multi chain polymer, poly functional step reaction polymerization, prediction of gel point, molecular weight distribution in 3-dimensional step reaction polymers. Numerical problems.	**10h**
Unit 4	**Kinetics of ionic and co-ordination polymerization:** Kinetics of cationic polymerization, anionic polymerization, living polymers, kinetic expression for co-ordination polymerization. Smith-Ewart's kinetics. Numerical problems.	**10h**

Unit 5	**Kinetics of co-polymerization:** The co-polymeric equation, monomer reactivity ratios, ideal & alternating co-polymerization, instantaneous composition of feed and polymer, evaluation of monomer reactivity ratios, rate of co-polymerization, integration of co-polymer equation. Numerical problems.	**10h**

Text books:

1. Keith J Laidler. Chemical Kinetics; Tata Mc.Graw Hill; New Delhi, 1975.
2. Fred W.Billmeyer. Text book of Polymer Science; JR John Wiley & Sons, New York.1984.

References:

1. Premamoy Ghosh. Polymer Science and Technology of Plastics & Rubbers; Tata McGraw-Hill, N.Delhi,India, 1990.
2. Anil Kumar & S.K.Gupta. Fundaments of Polymer Science and Engineering; Tata Mc Graw Hill, New Delhi, 1978

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PT450:TRANSPORT PHENOMENA IN MATERIALS ENGINEERING-II		
Course Outcomes: Upon successful completion of this course, the students will be able to-		
CO1:	Explain the principles and governing equations of heat transfer by conduction	
CO2:	Explain the individual and overall heat transfer coefficients of convective heat transfer.	
CO3:	Apply the knowledge of heat transfer in designing different types of heat exchange equipment.	
CO4:	Explain the principles of diffusion and develop relevant mathematical relations.	
CO5:	Develop mathematical relations for mass transfer applications which involve binary mixtures in process engineering.	
Course Content:		
Unit 1	**Transport of Heat by Conduction**: Introduction, Fourier's Law and Newton's Law, Conduction, Conduction in Heat Sources, **C**onduction through a multi layered wall, General Heat Conduction Equation, Numerical Problems**.**	**10h**
Unit 2	**Transport of Heat by Convection:** Introduction, relation between individual and overall heat transfer coefficient. Heat Transfer During Fluid Flow in Cylindrical Pipes, Energy Balance in Heat Transfer by Convection Between a Cylindrical Pipe and a Flowing Fluid, Heat Transfer by Forced Convection from horizontal Cylinders, General Energy Equation, and Numerical Problems.	**10h**
Unit 3	**Heat exchangers:** Introduction, heat transfer to a jacket, double pipe heat exchanger, and Finned tube heat exchanger. Numerical Problems.	**10h**
Unit 4	**Mass Transport by Diffusion in the Solid State:** Introduction, Atomic Diffusion as a Random-Walk Process, Fick's First Law of Diffusion, One-Dimensional Non-Steady-State Diffusion in a Solid; Fick's Second Law of Diffusion, numerical problems.	**10h**
Unit 5	**Mass Transport in Fluids:** Introduction, Mass and Molar Fluxes in a Fluid, Equations of Diffusion with Convection in a Binary Mixture A–B, One-Dimensional Transport in a Binary Mixture of Ideal Gases, Equimolar Counter diffusion, One-Dimensional Steady-State Diffusion of Gas A Through Stationary	**10h**

	Gas B, Numerical problems.	

Text book: David R Gaskell, An Introduction to Transport Phenomena in Materials Engineering, 2nd Edition, Momentum press, LLC, New Jersey (2012).

References:

1. D. R. Poirier, G. H. Geiger, Transport Phenomena in Materials Processing, Wiley, (1998).
2. McCabe, W.L., Smith J C and Harriot P., Unit Operations of chemical Engineering, 6t^{h} ed., Mc Graw Hill, NY 2001.

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PT46L : PHYSICAL CHEMISTRY LAB (0-0-1.5)	
Course Outcomes: Upon successful completion of this course, the students will be able to-	
CO1:	Explain the fundamentals, procedures and significance of physical chemistry experiments;
CO2:	Work in team and Conduct experiments by adopting laboratory disciplines;
CO3:	Determine intensive and extensive physical properties of liquids and solids;
CO4:	Analyze, interpret and report the experimental data suitably.
Course Content:	
1. Determination of density and surface tension of pure liquids.	
2. Determination of viscosity of a binary liquid mixture using viscometer.	
3. Determination of molecular weight of a non volatile substance by cryoscopic method using water as a solvent.	
4. Determination of molecular weight of a non-volatile substance by cryoscopic method using benzene as a solvent.	
5. Determination of molecular weight of a compound using Landsberg's apparatus by ebulioscopic method.	
6. Determination of degree of dissociation of a electrolyte (KCI) by cryoscopic method.	
7. Determination of degree of hydrolysis of potassium acetate near 0 ^{o}C.	
8. Determination of heat of neutralization of a monobasic acid.	
9. Determination of partition coefficient.	
10. First order kinetics - Acid hydrolysis of methyl acetate.	
11. Second order kinetics - Potassium per sulfate and potassium iodide.	
12. Langmuir's adsorption isotherm - adsorption of acetic acid on activated charcoal.	
13. Determination of molar heat of solution of a sparingly soluble organic acid by solubility method.	
14. Determination of degree of association of benzoic acid.	
15. Chemical equilibrium in solutions - validity of law of mass action.	

16. Determination of partial molar volume of NaCl solution.

Text book: David P. Shoemaker and Carl W.Garland, Experiments in physical chemistry, Mc-Graw Hill, 2nd Edition, NewYork, 1967.

References:

1. Physical Chemistry Lab Manual (Department of PST).
2. J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 16th Edition, Meerut, 2006.

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PT47L: CHEMICAL ENGINEERING LAB (0-0-1.5)

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

CO1:	Acquire the knowledge of unit conversion and concept of dimensional homogeneity.
CO2:	Learn usage of steam tables, nomographs and other property tables.
CO3:	Familiarize with conducting experiments on different types of heat exchangers and distillation methods.
CO4:	Experimentally generate VLE data and its validation with literature.

Course Content: List of experiments

1. Double pipe heat exchanger
2. Heat transfer in packed beds
3. Heat transfer through bare and finned tubes
4. Heat transfer in jacketed vessel
5. Calibration of thermocouples
6. Simple distillation
7. Packed bed distillation
8. Steam distillation
9. Vapour- liquid equillibrium
10. Tray drier
11. Condensers
12. Study of Single effect evaporator

Text books:

1. McCabe, W.L. and Smith J C. Unit Operations of chemical Engineering, 6th Edn., Mc Graw Hill, New York , 2001.

References:

1. Treybal, R. E. Mass-transfer operations; 3d ed.; McGraw-Hill: New York, 1980.

2. Don Green, Robert Perry, Perry's Chemical Engineers Hand Book, 8th ed.; Mcgraw-hill, 2007.

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HU410: ENVIRONMENTAL STUDIES (2-0-0)

Course Outcome: At the end of the course, students will have gained complete fundamental concepts of Environmental pollution sources, their impacts, control measures and preventive actions. The course also reinforces the concepts of role of individuals, NGOs and Governmental organizations, legal frame work, Acts, Regulations and Rules pertaining to Environmental Protection and Conservation.

Learning Objectives:

- Understand the basic concepts of earth's spheres, ecosystem and food chain
- Know the different types of pollution sources and their impacts on the environmental compartments such as water, air, land and ecosystems
- Appreciate and understand the importance of various cycles of elements
- Assess the energy requirements, different forms of energy. Conventional and alternative energy sources
- Get a feel of current environmental issues of concern such as urbanization, population, climate change, ozone layer depletion etc.,
- Know the role of individuals and other related agencies including governmental organizations involved in Environmental Protection and Pollution Control

Course Content:

1. Environment, spheres of earth (lithosphere, hydrosphere, atmosphere, biosphere); Ecosystem-Balanced ecosystem, Biome, food chain and food web.
2. Effects of human activities on environment-Agriculture, Housing, Industry, Mining and Transportation activities, Environmental Impact Assessment (EIA), Sustainable Development.
3. Natural resources - Water resources-Availability and quality aspects. Water borne diseases, water induced diseases, Fluoride problems in drinking water. Mineral Resources; Forest Resources.
4. Biogeochemical Cycles - Carbon, Nitrogen, Phosphorus and Sulphur Cycles.
5. Energy- Different types of energy, Electro-magnetic radiation. Conventional energy

sources.

6. Non-conventional sources-hydro electric fossil fuel based nuclear, solar, biomass and biogas.
7. Hydrogen as an alternative future source of energy, Environmental pollution and their effects.
8. Water pollution, land pollution, noise pollution, public health aspects.
9. Current Environmental issues of importance: population growth; climate change; global warming- effects, urbanisation, automobile pollution; acid rain, ozone layer depletion, animal husbandry.
10. Environmental protection- role of government, legal aspects, initiatives by non-governmental organization, environmental education, women education.

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V Semester

PT510: RUBBER TECHNOLOGY (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the basics of latex, natural and synthetic rubbers	
CO2:	Design rubber compounds based on end-use requirements	
CO3:	Evaluate and judge the quality of raw materials used in rubber and latex industry	
CO4:	Explain the basic concepts of textiles used in rubber products	
Course Content:		
Unit 1	**Rubber materials:** Sources, manufacturing (outline), grading, types, basic mix-design, processing, vulcanization and properties of- NR, SBR, NBR, CR, IIR, EPDM. Main characteristics of the following rubbers: BR, IR, Silicon, Fluorocarbon, Acrylate, polyurethane, polysulphides, chloro sulphonated polyethylene.	**10h**
Unit 2	**Mix design and selection of polymer:** compound design for low cost, high strength, maximum resistance to hydrocarbon oils and solvents; maximum resistance to heat aging, resistance to weathering and ozone, for electrical insulation, conducting, high resilience, Low set, flex cracking resistance, microcellular and multicellular structure, flame resistance, low temperature flexibility and processibility.	**10h**
Unit 3	**Fiber Reinforcements:** Textile terminologies; spinning process (synthetic fibers: melt spinning, solution spinning: wet and dry spinning), properties and applications of cotton, rayon, polyamide, polyester, glass, aramid and steel wire for use in rubber products, pretreatment methods and rubberizing process.	**10h**
Unit 4	**NR Latex:** preservation, concentration, stabilization, gelation. Simple latex mix design; maturation, de-aeration of latex compounds, preparation of dispersions and emulsions. Latex Testing: Sampling, total solid content, dry rubber content, pH, VFA number, KOH number, mechanical and chemical stability.	**10h**
Unit 5	**Specification and Standardization of Raw Materials**: Sieve residue test, heat loss, ash content, aniline point, melting point, boiling point, Softening point,	**10h**

	acetone extraction test, pH, plasticity/viscosity of raw polymer and compounded rubber, DBP absorption, iodine adsorption number.	

Text book:

1. Brendan Rodgers (Edr), Rubber compounding: Chemistry and Application, Marcell Dekker Inc., NY, 2004.

References:

1. D.C. Blackley, Synthetic Rubbers Their Chemistry & Technology, Applied Science Publishers, London & New York, 1983.
2. J.A.Brydron, Rubbery Materials & Their Compounds, Elsevier Applied Science Publishers London & New York. 1988.
3. C.M.Blow & C.Hepburn, Rubber Technology Handbook, Butter worth Scientific London, 1982.

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PT520: RHEOLOGY OF POLYMERS (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to		
CO1:	Explain the behavior of non Newtonian fluids and develop models for viscoelastic materials using spring and dashpot.	
CO2:	Develop mathematical model for flow of non Newtonian fluid through circular and slit dies and understand the significance of correction factors.	
CO3:	Develop mathematical model for flow of non Newtonian fluid through geometrically complex dies and understand the relationship between the rheological properties, molecular parameters and temperature.	
CO4:	Describe rheomertic experiments, analyze and interpret the results.	
CO5:	Apply rheology concepts in moulds/die design, melt processing operations. Further the student should learn response of polymers to dynamic loading.	
Course Content:		
Unit 1	**Introduction:** Fundamentals of rheology, stress, strain, shear stess, shear rate, ideal fluid, ideal solid, stress relaxation, creep, Types of fluids. Newtonian &non Newtonian fluids. Visco plastic fluid model, Ellis model, Eyring Powell model, Carreau model, Boltzmann Superposition Principle. **Rheological equations of state for viscoelastic fluids:** rheological equations of state, viscoelastic models (Maxwell, Voight and combined), Zener model , comparison of models.	**10h**
Unit 2	**Flow of molten polymers through circular and slit dies: D**erive equations for velocity, shear rate, volumetric flow rate for Newtonian & non Newtonian fluids. flow in the entrance region, Bagley's end correction, Rabinowitch correction factor, Slip velocity. **Swell ratio**– in long capillary and short capillary.	**10h**
Unit 3	**Flow of molten polymers through geometrically complex dies:** (a) Coni-cylindrical dies– ΔP due to shear, ΔP due to tensile flow. (b) Wedge shaped die.	**10h**

	Relationship between the rheological properties and molecular parameters of polymeric materials: The dependence of rheological properties on molecular parameters, effect of temperature and pressure on viscosity. WLF equation	
Unit 4	**Measurement of Flow properties:** Measurement of Flow properties by Capillary, Cone and plate and Coaxial cylinder Torque rheometer.	**10h**
Unit 5	**Applications of Rheology in polymer processing:** extrusion, Injection molding and calendaring. **Dynamic mechanical analysis:** tan δ concept, Dynamic modulus, and Time-temperature superposition.	**10h**

Text Books:

1. Applied Rheology in Polymer Processing, B R Gupta, Asian Books Private Limited, New Delhi, 2005
2. Plastics Engineering R J Crawford, 3rd Edn. Butterworth-Heinemann (2006).
3. Melt Rheology & its role in Plastics Processing, Dealy & Wissbrun, Van Nostrand Reinhold, New York (1990).

References:

1. Rheology of Polymers, Edward T. Severs, Reinhold Publishing Co. New York, (1962).
2. Flow Properties of Polymer melts - J.A.Brydson (Illife Books, London)
3. Rheology in Polymer Processing, Chang Dae Han, Academic Press, New York (1976)

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PT530: POLYMER STRUCTURE PROPERTY RELATIONSHIP (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain fundamentals of structure-property relationships or correlations between microstructure and properties;	
CO2:	Apply group contribution method to compute volumetric properties and solubility parameter of polymers;	
CO3:	Predict thermal/ calorimetric properties and explain the factors affecting them;	
CO4:	Explain the effect of molecular structure on mechanical and electrical properties of polymers;	
CO5:	Apply the knowledge of structure-property relationship to select the material for tailor made applications.	
Course Content:		
Unit 1	**Polymer properties:** Approach and the concept of chemical structure of polymers - Introduction, shapes and energy consideration, conformation and configuration (head-to-head, head-to-tail and tail-to-tail configuration and geometric isomerism with examples), tacticity, copolymers, hetero atomic polymers, molecular weight and distribution of molecular weights, melt viscosity, interchain and intrachain forces, microstructure, crystallinity; elastomers, fibers, plastics.	**10h**
Unit 2	**Physical structure of polymers:** Introduction to glass transition temperature; and their correlation with T_g and T_m (structural features). **Physical properties of polymers in relation to chemical structure:** Volumetric properties – volume and density, determination of volumetric properties by group additive methods; solubility – definition of solubility parameter and solubility limits.	**10h**
Unit 3	**Thermal and calorimetric properties:** Thermal expansion, heat capacity (C_p & C_v), transition temperatures (T_g & T_m) and factors affecting on T_g and T_m. Mathematical expressions (additive methods) to evaluate the thermal properties. Relationship between T_g and T_m of polymers. T_g/T_m and copolymers, enthalpy and entropy	**10h**

	Influence of process variables on the properties: introduction, orientation – degree of orientation, measurement of degree of orientation, uniaxial orientation, its meaning, change of properties by orientation in amorphous polymers, biaxial orientation, quantitative relationship for some physical quantities of orientation like density, thermal expansion, thermal conductivity, refractive index (birefringence), modulus of elasticity, mechanical damping, generalized stress-strain relationship for polymers.	
Unit 4	**Mechanical & Electrical Properties of Polymers:** Introduction, definition, Influence of molecular structure on mechanical and electrical properties of polymers factors affects on each property in detail with illustration and their commercial importance.	**10h**
Unit 5	**Influence of molecular structure to predict the properties of specialty polymers:** water soluble polymers, oil soluble polymers, oil insoluble polymers, flame retardant polymers, flexible polymers, water repellant polymers, heat resistant polymers, transparent polymers, adhesive polymers, corrosion resistant polymers.	**10h**

Text Books:

1. Properties of Polymers: correlations with chemical structure by Van Krevelen, 4th Edition, 2009, Elsevier Pub., NY.
2. Polymers: structure and Bulk properties – Patrick Meares, Van Nostrand, Pub., NY.
3. Structure property relationships in Polymers - Raymond B. Seymour & Charles E. Carraher, Plenum press, NY, 1984.

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PT540: PROCESSING TECHNOLOGY-I (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the basic principles of processing technology and processing machineries and the constructional features of extruder.	
CO2:	Explain the different dies and sizing setup and analyze the effect of processing parameters on the quality of extruded product.	
CO3:	Explain the constructional features of injection molding machines and analyze the effect of processing parameters on the quality of injection molded product.	
CO4:	Explain the constructional features of blow molding machines and analyze the effect of processing parameters on the quality of blow molded products.	
CO5:	Explain the process setup of different coating techniques and analyze the effect of processing parameters on the quality of coatings.	
Course Content:		
Unit 1	**Introduction**: Introduction to different molding and forming techniques used in polymer industry**.** Introduction to hydraulics and pneumatics. **Extrusion:** Different types of extruders, general constructional features of single screw extruders, machine design features eg: drives, types of screw, L/D ratio, compression ratio, flight depth, pitch, helix angle, screw clearance.	**10h**
Unit 2	**Extrusion**: General constructional features of dies, sizing and haul-off equipment for extrusion of monofilaments, rods, profiles, tubes, blown film, flat film, sheet, Heating, cooling and temperature control methods. **Extrusion:** Qualitative understanding of mechanism of screw extrusion and effects of screw and die design analysis of flow in extruder breaker plates and screens, screw speed and temperature on output and quality of extrudates. General features of twin screw machines. Master-batch mixers. Vented extruders, vacuum and heated hoppers, co-extrusion.	**10h**
Unit 3	**Injection moulding**: General constructional features of Injection moulding machines - specifications of machines. Methods of temperature control, Types of Injection moulding machines, limitations of ram type machines, types of	**12h**

	clamping - Toggle and hydraulic clamps, clamp force requirements. Injection moulding variables for ram and screw type machines (temp., pressure, time). Factors affecting melt temperature and pressure and the influence of these parameters on flow in the mould cavity. **Injection moulding:** Analysis of the time cycle. Cavity pressure- time curves for injection machines, Factors influencing frozen-in strains and their assessment. Points to be considered when injection moulding - granule shape, size and hygroscopy, specific heat, latent heat and thermal conductivity over a temperature range, flow properties to include consideration of effects of defects such as sharkskin, elastic turbulence, relaxation time and influence of T_g, T_m and crystal growth rates and cooling rates to impact strength, shrinkage etc. Hydraulic control systems for injection moulding	
Unit 4	**Blow moulding**: General principles of machines and processes for manufacture of bottles and other hollow products by extrusion blow moulding, injection blow moulding and stretch blow moulding. Parison control in relation to processing conditions and choice of materials. Mould cooling, cycle times, trimming and finishing. Material and design factors affecting bottle performance. Blow moulding Nomenclature, Bottle terminology, Control for blow molding, Trouble shooting-6Processing problems and solutions, blow moulding of highly irregular shaped products, Multi layer containers.	**10h**
Unit 5	**Coating**: Extrusion coating and laminating; wire coating, Melt roll coating, Transfer-coating, Powder-coating, electrostatic spray coating, flame spraying, dip coating and fluidized bed coating, Dip coating.	**8h**
Text book: A. Brent strong ,'Plastics: Materials and processing', Prentice-Hall Englewood cliffs, 2006		
References: 1. Isayev, Injection molding and compression molding fundamentals, Marcel Dekker,2010 2. Alan Griff ,Plastics Extrusion Technology, Krieger Publishing Company,1996 3. Rosato and Rosato. Injection Moulding Hand book, Hanser Publishers,2010 4. Rosato and Rosato, Blow Moulding Hand book , Hanser Publishers,2010		

5. Ed.Corish ,Concise Encyclopedia of Plastics Processing and applications, , Pergamon Press,1996

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PT550: COMPOUNDING TECHNOLOGY (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the properties of different additives, principle and operation of compounding machineries	
CO2:	Explain the properties, types and mechanism of processing aids, mechanical property modifiers and anti-ageing additives	
CO3:	Explain the properties, types and mechanism of surface property and optical property modifiers.	
CO4:	Explain the importance, function and different rubber compounding additives	
CO5:	Explain the compounding principle of polymer for specific application	
Course Content:		
Unit 1	**Introduction to Polymer Compounding:** Limitations of raw polymeric (Plastics and Elastomers) materials; need for compounding. Properties & Technical requirements of additives. Compounding machineries & parameters – different types of mixing roll mills, internal mixers, solution mixers and extruders.	**10h**
Unit 2	**Classification, Role, Mechanism, Suitability and Examples of following additives:** Additives which assist in processing: Stabilizers, Lubricants, Processing aids. Additives which modify mechanical properties: Plasticizers, Reinforcing fillers, Nano fillers, Toughening agents. Additives which reduce formulation costs: Fillers and Extenders. Anti-ageing additives: UV Stabilizers, Antioxidants.	**10h**
Unit 3	**Classification, Role, Mechanism, Suitability and Examples of following additives:** Additives which modify surface properties: Antistatic agents, Antiwear additives, Adhesion promoters, Antiblock additives/Slip additives. Additives which modify optical properties: Colorants, Pigments, Optical	**10h**

	brighteners, functional colors. Other additives: Blowing agents, Flame retardants, Specialty additives, Conducting fillers.	
Unit 4	**Functions and examples of rubber compounding additives:** Antiozonants, activators, peptizers, blowing agents, softeners, extenders, pigments, tackifiers, release agents, reclaimed rubber, factice, ground crumb, mineral rubber, retarders. **Fillers for elastomers:** Reinforcing and extending fillers; black and non-black fillers. Outline of the manufacture of carbon black, classification of carbon black. **Curing Systems:** Conventional, semi-EV and EV systems, peroxides, metal oxides and resins, classification and examples of accelerators.	**10h**
Unit 5	Compounding Criteria, Cost - Quality Balancing. **Case studies:** compounding of PF, PVC, PP **Case studies:** compounding of NR and Synthetic Rubber (SBR)	**10h**

Text books:

1. R Gachtor and H Muller. Plastic Additives, 3rd edition, Hanser Gardner Publications, Munich, Germany, 1991.
2. R F Grossman and J T Lutz Jr. Polymer Modifiers and Additives. Marcel Dekker, New York, 2001.
3. Brendan Rodgers. Rubber Compounding: Chemistry and Applications, 2nd edition, Taylor and Francis, New York, 2015.

References:

1. C M Blow. Rubber Technology and Manufacture, Butter worth Scientific Publications, London, 1971.
2. F W Barlow. Rubber compounding: Principles, Materials and Techniques, 2nd edition, Marcel Dekker, CRC Press, New York, 1993.
3. J A Brydson. Plastics Materials, 6th edition, Butter Worths publications, London, 1995.
4. J A Brydson. Rubbery Materials & their compounds, Elsevier Applied Science Publishers, London, New York, 1988.

5. Ica Manas-Zloczower. Mixing and Compounding of Polymers: Theory and Practice. 3rd edition, Hanser Gardner Publications, Munich, Germany, 2012.

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PT560: POLYMER ANALYSIS AND EVALUATION (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain analysis of polymers by physico-chemical methods.	
CO2:	Explain analysis of polymers using thermal methods;	
CO3:	Explain analysis of polymers using spectroscopic methods;	
CO4:	Explain analysis of polymers using X-ray and chromatographic techniques;	
CO5:	Explain analysis of polymers using microscopic methods;	
Course Content:		
Unit 1	**Fundamentals:** Introduction to analysis/ evaluation/ characterization of polymers; need and types of analysis. **Physical methods:** Introduction, theory, procedure and significance of the methods to determine- color, density, bulk factor, ash content and solvent extraction. Analysis of additives. Numerical problems. **Chemical methods:** Systematic analysis of plastics and rubber by chemical methods.	**10h**
Unit 2	**Thermal methods:** Introduction and types. Principle, theory, instrumentation, procedure, advantages, limitations and applications of- Differential Scanning Calorimeter (DSC), Thermo Gravimetric Analyzer (TGA), Thermo Mechanical Analyzer (TMA) and Dynamic Mechanical Analyzer (DMA). Interpretation of thermograms.	**10h**
Unit 3	**Spectroscopic methods:** Introduction and types. Principle, theory, instrumentation, procedure, advantages, limitations and applications of- Ultraviolet/ Visible (UV-Vis) spectroscopy; Fourier Transform Infrared (FTIR) spectroscopy and Nuclear Magnetic Resonance (NMR) spectroscopy. interpretation of spectrograms.	**10h**
Unit 4	**X-ray Diffractometry (XRD):** Introduction, principle, theory, instrumentation, procedure, advantages, limitations and applications of XRD. SAXS & WAXS. (interpretation of diffractogram and determination of percentage crystallinity.)	**10h**

	Chromatographic techniques: Introduction and types. Principle, theory, instrumentation, procedure, advantages, limitations, interpretation of chromatogram and applications of- Gel Permeation Chromatography (GPC) and Gas chromatography (GC).	
Unit 5	**Microscopic methods:** Introduction and types. Principle, theory, instrumentation, procedure, advantages, limitations and applications of- Optical Microscopy (OM), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) and Atomic Force Microscopy (AFM). Interpretation of micrographs.	**10h**

Text Book: Gurdeep Chatwal and Sham Anand. Instrumental Methods of Chemical Analysis, Himalaya Publisher, 1986.

References:

1. Fred W Billmeyer. Textbook of Polymer Science, John Wiley & Sons, New York, 2002.
2. A Tager. Physical Chemistry of Polymers, Mir Publishers, Moscow, 1978.
3. D Campbell and J R White. Polymer characterization- Physical Techniques, Chapman and Hall, UK, 1989.
4. K J Saunders. The Identification of Plastics and Rubber, Chapman & Hall, London, 1966.
5. William C Wake. Analysis of Rubber and Rubber like Polymers, Maclaren and sons, England, 1958.
6. E A Turi. Thermal Characterization of Polymeric Materials, Academic Press, New York, 1981.
7. J Brandrup and E H Immergut. Polymer Handbook, 3rd ed, John Wiley, NY, 1989.
8. P J Flory. Principles of Polymer Chemistry, Cornell University Press, Ithaca, NY, 1953.
9. Willard, Merritt, Dean and Settle. Instrumental Methods of Analysis, 7th ed, CBS Publishers, New Delhi, 1986.

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PT57L: POLYMER PREPARATION LAB (0-0-1.5)	
Course outcome: Upon successful completion of this course, the students will be able to-	
CO1:	Apply the theoretical knowledge to prepare and characterize the polymers.
CO2:	Synthesize polymers and copolymers by using different polymerization techniques
CO3:	Qualitatively analyze the prepared polymers.
CO4:	Quantitatively analyze the properties of given polymers.

List of experiments:

PART A (Polymer Preparation)

1. Bulk polymerization of styrene.
2. Emulsion polymerization of methylacrylate.
3. Suspension polymerization of styrene.
4. Solution polymerization of acrylonitrile.
5. Preparation of styrene –acrylonitrile by bulk polymerization.
6. Preparation of poly acrylamide by free radical polymerization.
7. Synthesis of urea - formaldehyde by condensation polymerization.
8. Preparation of polyaniline.
9. Synthesis of polysulphide rubber.

PART B (Estimation)

1. Determination of acid value for a given sample.
2. Estimation of percent hydrolysable chlorine present in epoxy resin.
3. Determination of acetyl value of cellulose acetate by acetylation method
4. Estimation of epoxy equivalent weight
5. Estimation of the extent of polymer in different solvent.
6. Determination of hydroxyl value by acetylation method.
7. Determination of concentration of hydrogen peroxide.

Text Book: Practicals in Polymer Science - Synthesis and Qualitative & Quantitative Analysis of Macromolecules, Dr.Siddaramaiah, CBS publishers & distributors pvt ltd. New Delhi 2012.

References:

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

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PT58L: PROCESSING TECHNOLOGY LAB (0-0-1.5)

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

CO1:	Demonstrate the fundamentals, procedures and significance of processing techniques
CO2:	Operate and practice processing equipments
CO3:	Optimize the cycle time to make defect free products
CO4:	Analyze, interpret and report the output data suitably.

List of Experiments:

i. Hand operated injection moulding machine: Different materials and moulds; and optimization of cycle time.

ii. Semi-automatic injection moulding machine. Different materials, moulds and optimization of cycle time.

iii. Automatic Injection Moulding.

iv. Pneumatic injection moulding, different materials, moulds and optimization of cycle time.

v. Hand operated blow moulding machine. Different materials and optimization of cycle time.

vi. Pneumatic blow molding machine.

vii. Determination of melt flow index for different materials.

viii. Extrusion of strands / film and Pelletization.

ix. Variation in properties of CV system and EV system in Natural rubber compound.

x. Rubber compounding for at-least 2 specific products.

xi. Effect of mastication level on Natural Rubber compounds. Masticate the rubber for different times (5, 10, 15, 20 minutes) and find out the variation in solution viscosity. Plot solution viscosity Vs time.

xii. Rubber compounding using Haake batch mixer

xiii. Blending of two polymers using Haake twin screw Extruder.

References:

i. PROCESSING TECHNOLOGY LABORATORY MANUAL (Department of PST).

ii. Isayev, Injection molding and compression molding fundamentals, Marcel Dekker,2010

iii. Alan Griff ,Plastics Extrusion Technology, Krieger Publishing Company,1996

iv. Rosato and Rosato. Injection Moulding Hand book, Hanser Publishers,2010

v. Rosato and Rosato, Blow Moulding Hand book , Hanser Publishers,2010.

vi. Ed.Corish ,Concise Encyclopedia of Plastics Processing and applications, , Pergamon Press,1996

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VI Semester

PT610: TESTING OF POLYMERS (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to–		
CO1:	Explain the basics of process instrumentation	
CO2:	Explain the different standards, specifications and test procedure to evaluate thermal properties of polymers	
CO3:	Explain test procedure to evaluate mechanical properties of plastics	
CO4:	Explain test procedure to evaluate–optical, electrical and flammability properties of plastics	
CO5:	Explain test procedure to evaluate environmental, nondestructive properties and polymer product testing	
Course Content:		
Unit 1	**Introduction to Instrumentation:** Qualities of measurement; measurement of: temperature, pressure, flow, level & mechanical measurements; Composition analysis; process instrumentation.	**10h**
Unit 2	**Introduction:** Need for testing, need for standards and specifications, national and international standards, quality control, limitations and accuracy of test data; validity of test methods. Classification of tests based on: properties (mechanical/ thermal/ etc); duration (long/ short term); destructive/ non-destructive; etc. Definition of: strength, ageing & failure. Basics of: Failure mechanism (fracture mechanics); identification of ageing & factors affecting it; and material responses to different types of forces. **Specimen preparation and conditioning:** Shape and size of test specimen, standards for test specimen preparation like molding, machining, stamping and punching of specimens, and their effects on test results. Conditioning of specimens. **Thermal properties:** Heat deflection temperature, Vicat softening point, thermal conductivity and brittleness temperature.	**10h**

Unit 3	**Mechanical properties:** **Short term strength-** Tensile, compression, flexural, shear, impact resistance, toughness, tear resistance, abrasion resistance and hardness. **Long term strength-** Dynamic stress and strain; creep, stress relaxation, flex to fatigue properties.	**10h**
Unit 4	**Optical properties:** Gloss, haze, refractive index, degree of yellowness, transmittance, colour, photo elastic properties. **Electrical properties:** Insulation, volume resistivity, surface resistivity, breakdown voltage, dielectric strength, arc resistance, dielectric constant, power factor. **Flammability properties:** Oxygen index, critical temperature index CTG, fire behavior (using cone calorimeter), smoke density, flammability test, ignition properties, surface burning characteristics.	**10h**
Unit 5	**Environmental properties**: Environmental stress cracking, weathering properties, toxicity, resistance to chemicals. **Non-destructive testing methods:** X-rays, ultrasonic testing, Infra Red and Microwave techniques. **Polymer product testing**: Brief testing procedures for different products like- films, pipes, tubes, laminates, adhesives, tires & containers.	**10h**
Text book: Vishu Shah, Handbook of plastics testing technology, John Wiley, NewYork, 2007		
References: 1. Donal P Eckman, Industrial Instrumentation, Wiley, NewYork, 2006. 2. R.P. Brown, Hand book of Polymer testing , Mercel Dekker ,Newyork,1998 3. R.P. Brown, Physical testing of rubbers, Applied science publishers, London,1979. 4. Relevant ASTM and ISO standards		

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PT620: POLYMER BLENDS AND ALLOYS (4-0-0) **Course outcomes:** Upon successful completion of this course, the student will be able to-		
CO1:	Explain the fundamentals of polymer blends, alloys and blending equipments;	
CO2:	Explain thermodynamic aspects, phase diagram and morphology of polymer blends;	
CO3:	Explain miscibility and compatibilization of blends;	
CO4:	Explain toughening and characterization of blends;	
CO5:	Explain interpenetrating polymeric networks, and Design polymer blend/ alloy to meet requirements.	
Course Content:		
Unit 1	**Fundamentals of Polymer Blends:** Historical outline of industrial development of polymer blends and alloys, reasons for blending, definitions of terms used in polymer blends & alloys. Types of Polymer blends; blend components' selection criteria, methods of blending, fundamental principles for development of polymer alloys and blends; Designing a polymer blend. **Blending equipments:** Mixers' and their types, like- banbury, hot and cold mixers, twin screw compounders, two-roll mills, etc. Design features of these equipments like rotor types, screws and their various types; flow behavior of the plastic material in the mixing equipments, theory of mixing.	**10h**
Unit 2	**Thermodynamic aspects of blending:** combinatorial entropy of mixing, enthalpy of mixing, general principles of phase equilibria calculation, LCST and UCST concepts, theories of liquid mixtures containing polymer: Huggins-Flory theory, equation of state theories, Gas lattice model. **Phase behavior:** introduction to phase behavior, mechanisms of phase separation- Spinodal decomposition and Nucleation & Growth, and various phase diagrams of polymer blends. **Morphology**- definition, influence of phase separation on the crystallization and morphology, types of morphologies.	**10h**
Unit 3	**Factors affecting miscibility of polymer blends**- Thermodynamics, compatibility, solubility parameter, interaction parameter, composition, molecular weight, transition temperature, mechanism of blending, etc. Properties of miscible	**10h**

	and immiscible blends. **Compatibilization (Alloying) Methods:** Introduction, types and role of compatibilizer, compatibilization methods, mechanism and properties of compatibilized blends. Degree of compatibilization.	
Unit 4	**Polymer Toughening:** Mechanism and theory of toughening, Toughening of thermoplastics and thermosets; Thermoplastic elastomers (TPEs). **Characterization of polymer blends:** Miscibility determination: Phase equilibria methods- turbidity, light scattering, SAXS, etc; Measurement of interaction parameter: direct methods & ternary system containing solvent; Indirect methods- T_g (DSC, DMA), IR, Microscopy, density, viscosity, RI.	**10h**
Unit 5	**Interpenetrating Polymeric Networks (IPNs):** Introduction, classification, method of formation of IPNs, properties and uses, role of cross links, and their importance. **Blends of engineering and commodity plastics:** like PVC/ABS, PVC/SAN, PVC/NBR, PC/PET, PC/PBT, PC/ABS and PPO/HIPS [Case study including properties and applications].	**10h**
Text book: L A Utracki. Polymer blends and alloys, Hanser Publication, 1989.		

References

1. Paul and Newman. Polymer blends, Academic press, NewYork, 1978.
2. Lloyd M Robeson. Polymer blends– A comprehensive review, Hanser publishers, 2007.
3. John Mason and Leslie H Sperling. Polymer blends and composites, Plenum Press, New York, 1976.
4. http://nptel.ac.in/courses/113105028/35

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PT630: POLYMER COMPOSITES (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Classify composite materials and explain functions of each constituent.	
CO2:	Explain the curing chemistry and concepts of interfacial adhesion to probe the structure-property relationships of thermosets.	
CO3:	Select suitable reinforcement for intended application and apply the mathematical model to evaluate the composite properties.	
CO4:	Describe and apply suitable composite processing technique for specific product.	
CO5:	Test and apply the knowledge of composites to develop cost effective/eco-friendly/sustainable products.	
Course Content:		
Unit 1	**Introduction to Composites:** Definition, Raw Materials, Functions of constituent phases, Classification of composites, Advantages and limitations of polymer matrix composites over MMC and CMC, Applications. **Thermoplastic Matrix:** Physical, chemical, thermal and mechanical properties of Polyolefins, polyacetal, PC, ABS, Nylon 6 & 66, PET, PAEK, PPS.	**10h**
Unit 2	**Thermoset Matrix:** Raw materials, epoxy, unsaturated polyester resin, alkyd resin, vinyl ester, PF resin – curing chemistry, physical and chemical properties, thermal behaviour and mechanical properties. **Coupling agents:** Function, chemistry, examples and applications.	**10h**
Unit 3	**Reinforcements and fillers:** Types of reinforcements, manufacturing, properties, chemistry and applications. Flakes and Fibers (both natural and synthetic reinforcements should be considered). High performance fibers (glass, carbon, aramid and boron fibers) properties, chemistry and applications. Fillers (Silica, calcium carbonate, talc, etc.) functions, properties. Mathematical models to predict composite properties, Numerical problems based on rule of mixtures.	**10h**
Unit 4	**Processing of polymer composites:** Gelation time, curing/crosslinking reaction, prepreg making, Hand lay-up, Spray up, Balloon molding, Compression &	**10h**

	Transfer Molding of reinforced thermoset resins, RTM, VARTM, VERTM, Pressure and Vacuum bag process, Autoclave molding, Filament winding, Pultrusion, Reinforced RIM, Injection Moulding of Thermosets, SMC and DMC – procedure, advantages and disadvantages of each method. Processing of thermoplastic composites.	
Unit 5	**Testing of composites:** Factors affecting on performance of composites, aspect ratio, void content, mechanical properties- tensile, compression, flexural, ILSS, impact, Non destructive testing and failure analysis. **Specific applications of composites:** Aerospace, Automobile, Construction, Marine etc.	**10h**

Text books:

1. S T Peters. Handbook of Composites, 2nd edition, Chapman and Hall, London, 1998.
2. Sanjay K Mazumdar. Composite manufacturing, materials, product and process engineering, CRC Press, London, 2002.

References:

1. D V Rosato and D V Rosato. Reinforced Plastics Handbook, 3rd edition, Elsevier, UK, 2004.
2. K K Chawla. Composite Materials Science and Engineering, 2nd edition, Springer publications, New York, 1998.
3. T G. Gutowski. Advanced composite manufacturing, 1st edition, John Wily and Sons, New Jersey, 1997.
4. L C Hollaway. Handbook of Polymer Composites for Engineers, 1st edition, Woodhead Publishing, UK, 1994.
5. J C Bittence and F Cverna. Engineering Plastics and Composites, 2nd edition, ASM International, Materials Park, OH, 1990.

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PT640: PROCESSING TECHNOLOGY-II (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain Compression and Transfer moulding process.	
CO2:	Explain Rotational moulding and Reaction injection molding process	
CO3:	Explain Calendering and Thermoforming process	
CO4:	Explain Structural foam moulding and micro-processing techniques	
CO5:	Select suitable post processing method for polymer products	
Course Content:		
Unit 1	**Introduction:** Different moulding and forming techniques used in polymer industry, Materials used, characteristics of TS materials, forms of materials, shrinkage, bulk factor, the interplay of heat, pressure, friction, catalysts, sources of heat and pressure. Shelf life, flow cure characteristics, Cup flow test and spiral flow test. **Compression Moulding**: The machines, Compression press, the different types of moulds, the compression moulding cycles, breathing, trouble shooting, Compression moulding of thermoplastics. advantages and drawbacks of the process **Transfer moulding:** Fundamental principles of transfer moulding, Equipments used: Different types of transfer moulding - pot, plunger and screw transfer moulding, Transfer molds: Integral moulds and auxiliary ram moulds. Moulding cycles, moulding tolerances. Materials used Heating requirements**.** Advantages over compression moulding **Auxiliary processes**: Preheating and Deflashing techniques	**10h**
Unit 2	**Rotational moulding:** the process, different types, advantages and limitations, type of materials that can be processed and moulds used. **Slush moulding: P**rinciple, methods, material and moulds **Reaction Injection Moulding**:- Introduction, advantages and disadvantages, machinery, materials, processing and tooling.	**10h**

Unit 3	**Thermoforming** : Vacuum forming: Materials for thermoforming, the working of the elementary vacuum forming machine, techniques of vacuum forming - simple vacuum forming, drape forming, plug -assist forming, snap-back vacuum forming, pressure snap- back vacuum forming, plug and ring vacuum forming, blow back forming, Matched mould forming, advantages and limitations of vacuum forming. Pressure forming - advantages over vacuum forming, means of application of pressure in pneumatic and mechanical., Types of heating equipment, Mould design and construction, Control of thinning. Finishing techniques, Continuous forming methods. **Calendering:** Consideration of materials, General constructional features of calenders, 2 roll, 3 roll, 4 roll and 5 roll calenders, vertical, inclined, L type, Z type configurations, embossing and laminating machines. Problems of uniformity of temperature control, melt flow, thickness and tension control. Reinforcements of modern machines - drilled .rolls and infra- red heaters, cambered bowls, cross-axis and roll bending. Different methods of supplying feed stocks, skim coating and frictioning processes. Calendering faults - errors due to formulation, compounding and calendering operation.	**10h**
Unit 4	**Structural foam Moulding:** Introduction, different methods, machinery, Advantages and Disadvantages, blowing agents, co-injection, materials processing and tooling. **Micro processing techniques:** Injection Moulding, Extrusion and Blow moulding	**10h**
Unit 5	**Fabrication, finishing and decorating of plastics**; Assembly of fabricated parts - Adhesive bonding, Mechanical fastening, Welding, Thermal sealing, Solvent bonding, Screen Printing, electroplating, Vacuum Metalizing and Hot stamping.	**10h**

Text books:

1. Joel Fredos, Plastics Engineering Handbook, 2nd-3rd edition, Van Nostrand Reinhold , Newyork, 1976.
2. A. Brent strong, Plastics: Materials and processing, , 3rd illustrated, Pearson Prentice Hall, 2006

References:

i. Reginald Alfred Elden and A. D. Swan, Calendaring of plastics, Plastics Institute, 1971

ii. Middleman, Fundamentals of Polymer processing ,McGraw Hill, Newyork,1977

iii. D.H. Morton Jones Polymer processing, Chapman & Hall, 1989

iv. Paul Bruins, Basic principles of Rotational moulding, Gordon and Breach science publishers, Inc, Newyork,1971

v. James L. Throne, Technology of Thermoforming, Hanser Gardner Publications, 1996

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PT650: PRODUCT DESIGN (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain basic principles of plastic product design and suitable material for a specific product.	
CO2:	Explain design features and engineering design	
CO3:	Explain and construct creep curves for designing of plastic components and explain the concepts of mechanical behavior of composites	
CO4:	Explain the design concepts of snap fits , parts undergoing dynamic loads and bearings	
CO5:	Explain the design concepts tailor made applications	
Course Content:		
Unit 1	**Introduction**– Material selection based on end use requirement of various products; principles of product design.	**10h**
Unit 2	**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	**10h**
Unit 3	**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, (reference: Polymer eng by Crawford chapter 3) 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.	**10h**
Unit 4	Design of snap fits, ribbed sections Dynamic loading of plastics	**10h**

	Designing of polymer bearing and wear surfaces	
Unit 5	Designing of elastomeric ring seals operation Designing plastic pipes	**10h**

Text books:

1. R.D.Beck, Plastics product design,Van Nostrand– Reinhold, 2006
2. Dym, Product design with plastics, Industrial Press, 2010
3. R.J.Crawford ,Plastics Engineering, 3rd edition, Butterworth Heinemann, 2012

References:

1. Dubois & Pribble ,Plastics Mold Engineering Hand book ,Van Nostrand,2006
2. E.Miller, Plastics product design hand book – part A and part B ,Marcel Dekker, N.Y,2006
3. Levy & Dubois, Plastics Product Design Engineering Hand Book ,Champman and Hall.,2010

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PT661: NANOTECHNOLOGY (4-0-0) (Elective-1) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the fundamentals, classification, production and applications of nano-materials	
CO2:	Explain the structure, property and modifications of nanoclay, its characterizations and applications	
CO3:	Explain the fundamentals, types, properties and production of CNTs	
CO4:	Explain fabrication of nanocomposites and applications of CNTs and graphene	
CO5:	Apply the major characterization techniques of nanomaterials	
Course Content:		
Unit 1	**Introduction:** Introduction to nanotechnology, difference between micro and nanocomposites or materials, history, definition, types, classification, Types of methods to produce nanostrucutred materials (atleast four methods to be covered), Nanorods, Nanowires- synthesis, properties, characterization and applications, Nanoparticles (silver nanoparticle, Al_2O_3, ZnO, TiO_2), Nanoplatelet, Nanofiber	**10h**
Unit 2	**Nanoclay-** Introduction, chemistry, types, properties and uses of nanoclay, surface modification of nanoclay with different organic compounds and their properties, reason for modification of nanoclay, Preparative methods of nanocomposites - from solution, In situ intercalative polymerization method, Melt intercalation; types of nanocaly composites – Intercalation and exfoliation and their characterization, application of nanoclay filled polymer nanocomposites	**10h**
Unit 3	**Carbon nanotubes (CNTs)-** Chemistry, types, structure, properties and applications. Comparison of CNTs with graphite fibers, SWNTS & MWNTs, production of CNTs, purification, surface modification of CNTs, properties- mechanical, thermal, morphological, electrical properties. Fullerenes - structure, properties and applications	**10h**
Unit 4	Methods of fabrication of CNT-polymer composites, properties of CNTs composites, characterizations of Nanocomposites by x-ray, electrical, thermal, optical, Raman spectra and TEM. Application of CNT-polymer composites	**10h**

	Graphene – structure, properties and applications	
Unit 5	**Techniques used for the characterization of nocomposites–** Mechanical properties, Dynamic mechanical analysis, Tensile properties, Flexural properties, Heat distortion temperature, Thermal stability, Fire retardant properties, gas barrier properties, conductivity, Optical transparency, Biodegradability of biodegradable polymers-based nanocomposites, Crystallization behavior and morphology of Nanocomposites – Rheology, Melt rheology and structure–property relationship.	**10h**

Text Book: Polymer layered silicate and silica nano composites, Y.C. Ke, P. Stroeve and F.S. Wang**,** Elsevier, 2005.

References:

1. B. K. G. Theng. Formation and properties of clay-polymer complexes. Elsevier, Amsterdam, 1979.
2. B.K.G. Theng. Chemistry of clay-organic reactions. Wiley, New York, 1974.
3. V.Chirala, G.Marginean, W.Brandl and T.Iclanzan, Vapour grown carbon nanofibres-polypropylene composites and their properties in Carbon nanotubes edited by V.N. Popov and P.Lambin, p.227, Springer (2006), Netherlands.
4. Recent Advances in Polymer Nanocomposites; Editors: S. Thomas, G.E. Zaikov and S.V. Valsaraj, CRC Press, 2009
5. Progress in Polymers Nanocomposites Research Editors: Sabu Thomas, Gennady E. Zaikov, Novapublishers, 2009.

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PT662: ENGINEERING PLASTICS (4-0-0) (Elective-1) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the fundamentals of engineering polymers and its versatile applications;	
CO2:	Explain the manufacturing and process-ability of engineering polymers;	
CO3:	Explain the structure-property relationships of engineering polymers;	
CO4:	Explain the classification of engineering polymers and its blends with specific examples;	
CO5:	Explain the engineering applications and selection the suitable materials.	
Course Content:		
Unit 1	**Introduction:** The plastics industry– An overview. Definition of commodity polymers, engineering polymers & high-performance polymers (or tonnage polymers, vintage polymers & specialty polymers respectively). Difference between them (i.e. the classification of polymers based on functional applications to be understood). Classification of engineering polymers (based on chemical family; and also as engineering- plastics/ thermosets/ elastomers). Examples of some key makers & trade names of engineering polymers. Over-view of versatile applications of engineering polymers (engineering applications includes: mechanical units under stress, low friction components, heat and chemical resistant units, electrical parts, housings, high light transmission applications, building construction functions, and many miscellaneous uses); Specific examples of applications in automobile, aerospace, electrical & medical fields to be discussed in brief.	**10h**
Unit 2	Manufacturing (in brief), process-ability, structure-property relationships and the end use (applications) are to be discussed for the following engineering polymers with case studies: 1. **Fluropolymers:** PTFE, PCTFE, PFA, PVDF. 2. **Polyesters:** PET, PBT, PC, Polyarylate.	**10h**
Unit 3	3. **Polyamides:** Nylons (6, 66, 610, 11), Polyaramid. 4. **Imide Polymers:** Polyimides (PI), Polyetherimide (PEI), Polyamide	**10h**

	imides (PAI).	
Unit 4	5. **Sulfur containing polymers:** Polyphenelene Sulphide (PPS), Polyether sulfones (PES), Polysulphones (PSU). 6. **Oxygen based polymers**: Polyacetals (POM), Poly phenylene oxide (PPO) & Polyphenylene ether (PPE)	**10h**
Unit 5	7. **Ketone based polymers:** Polyketones (PEK, PEEK). 8. **Others:** Ultra High Molecular Weight Poly Ethylene (UHMWPE), Acrylonitrile butadiene styrene (ABS), & Engineering LCP. Brief discussion about engineering polymer blends: PC/ABS, PPE/PS-I, PA/ABS.	**10h**

Text Book: Irvin I Rubin. Handbook of plastic materials and technology, Wiley, 1990.

References:

1. Michael L Berins. Plastic Engineering handbook of the society of plastics industry Inc, 5th 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.

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PT663: FIBER TECHNOLOGY (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the fundamentals of fiber forming materials, structure-property relationships.	
CO2:	Describe the effect of process parameters on microstructure of fiber.	
CO3:	Explain the concepts of fiber processing and finishing operations.	
CO4:	Explain properties and applications of different fibers	
Course Content:		
Unit 1	**Introduction:** Basic terminologies like filament, yarn, cord, denier, tex, tenacity etc., classification of fiber, essential properties of textile fibers. **Production of fibers:** principle, technology, advantages and disadvantages of the following techniques; Melt spinning, Dry spinning, wet spinning process. Drawing of fibers.	**10h**
Unit 2	**Processing of fibers:** Twisting, texturization process, staple fiber formation. **Fiber structure:** unit cell, arrangement of molecules in crystallites, formation and arrangement of crystallites in fibers, measurement of crystallinity (density method, x-ray diffraction, thermal methods, spectroscopic methods), orientation and its measurement.	**10h**
Unit 3	**Types of fibers:** Natural, modified, synthetic, high-performance. Source, production, forms, properties and application of the following fibers: **Natural/ modified:** Cellulose, cotton, viscose, rayon, etc;	**10h**
Unit 4	Source, production, forms, properties and application of the following fibers- **Synthetic:** Polyamide (N6, N66), linear polyolefins, glass, polyester, acrylic and metallic fibers. Discussion about important **High-performance Fibers**.	**10h**
Unit 5	**Finishing:** purpose of finishes, location and fixation of finishes, penetration of fabric and fiber, graft copolymerization, types of finishes like shape retention finishes, firming and softening finishes water repellent finishes.	**10h**

	Dying of fibers: basic properties required for dyes, dye-ability of fibers, absorption of nonionic polymers, and absorption of non ionic dyes in ionic sites. Transformation of the dyes in the polymer. Light fastness, leveling, carrier dying.	
Text book: Manmade fibers; Science and Technology, Edt. H.F.Mark, S.M.Atlas & Cerina., Inter Science publishers, New York.		
Reference: A text book of Fiber Science & Technology, S.P Mishra, New age international publishers, New Delhi.		

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PT664: MODELING AND SIMULATION (PROPOSED SYLLABUS) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the basic principles of modeling of polymer matrix nanocomposites	
CO2:	Develop models using equations for Computational of Polymer flow inside the extruder	
CO3:	Develop models using equations for Computational of Polymer flow inside and outside the dies	
CO4:	Develop models using equations for Computational of Polymer flow in Spinning , Casting , Blowing and unsteady-State Processes like Blow Molding ,Thermoforming ,Injection Molding	
CO5:	Apply and analyze the computational mechanics of rubber and tires	
Course Content:		
Unit 1	**Modeling of Polymer Matrix Nanocomposites** Introduction ,Polymer Clay Nanocomposites and Coarse-Grained Models ,Coarse-Grained Components ,Methods and Timescales ,Off-Lattice (Continuum) Approach ,Discrete Lattice Approach ,Hybrid Approach ,Coarse-Grained Sheet Modeling and Simulation: Conformation and Dynamics of a Sheet ,Coarse-Grained Studies of Nanocomposites ,Probing Exfoliation and Dispersion ,Platelets in Composite Matrix ,Solvent Particles ,Polymer Matrix	**10h**
Unit 2	**Computational Polymer Processing (Part -1)** Introduction ,Polymer Processing ,Historical Notes on Computations ,Mathematical Modeling ,Governing Conservation Equations ,Constitutive Equations ,Dimensionless Groups ,Boundary Conditions ,Method of Solution ,Polymer Processing Flows, Extrusion ,Flow Inside the Extruder ,Current Trends and Future Challenges	**10h**
Unit 3	**Computational Polymer Processing (Part-2)** Flow in an Extruder Die (Contraction Flow) ,Flow Outside the Extruder – Extrudate Swell, Co -extrusion Flows ,Extrusion Die Design ,Post extrusion Operations ,Calendaring ,Roll Coating ,Wire Coating	**10h**
Unit 4	**Computational Polymer Processing (Part-3)** Fiber Spinning ,Film Casting ,Film Blowing ,Unsteady-State Processes :Blow Molding Thermoforming , Injection Molding ,Conclusions	10h

Unit 5	**Computational Mechanics of Rubber and Tires** Introduction, Nonlinear Finite Element Analysis, Incompressibility Conditions, Solution Strategy Treatment of Contact Constraints,Tire Modeling	**10h**

Text Book:

1. Purushottam D. Gujrati and Arkadii I. Leonov (Edr), Modeling and Simulation in Polymers, Wiley, Weinheim, 2010.

References:

1. Turner A.P.F, Karube.I and Wilson,G.S, Biosensors Fundamentals and applications, Oxford Univ. Press, 1990.
2. John H. Seinfeld and Leon Lapidus., Mathematical Methods in Chemical Engg., (Vol. 3), Process Modeling, Estimations and Identification. Prentice Hall, 1974.
3. Shyam S. Sablani., Handbook of Food and Bioprocess Modeling Techniques. C R C
4. Computational Nanotechnology: Modeling and Applications with MATLAB® edited by Sarhan M. Musa
5. Michael Rieth and Wolfram Schommers (Edr), Handbook of theoretical and computational Nanotechnology, 2006.
6. William. L Luyben, Process Modeling Simulation and Control for Chemical Engineering 2nd Edition, McGraw Hill, 1990
7. B.V.Babu, Process plant simulation, OXFORD university publication press, 2012.
8. Wayne Bequette.B, Process dynamics modeling and analysis and simulation,. Prentice Hall Inc, 2004.

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PT67L: POLYMER ANALYSIS AND CHARACTERIZATION LAB (0-0-1.5)

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

CO1:	Identify the polymers by the systematic qualitative analysis.
CO2:	Carry out quantitative analysis of polymers and additives.
CO3:	Characterize physical and thermal properties of polymers.
CO4:	Analyze and interpret the experimental data.

List of Experiments:

Part-A:

1. Determination of physical properties viz., (I) filler content, (ii) ash content (iii) moisture content and (iv) bulk density.
2. Seive analysis and DBP Value of a given carbon black sample.
3. Determination of surface area of carbon black sample by iodine adsorption method.
4. Determination of Aniline point and specific gravity of processing oil.
5. Estimation of saponification value of the given oil.
6. Determination of viscosity average molecular weight by viscometric method.
7. Determination of percentage of extractable ingredients present in rubber sample by solvent extraction.
8. Determination of molecular weight by end-group analysis.
9. TGA studies of polymer samples.
10. DSC studies of polymer samples.
11. FTIR studies of polymer sample

(Faculty in charge of this lab will design the experiment for 9-11)

Part-B

Qualitative analysis of polymers (polymer identification) HDPE, LDPE, PP, GPPS, HIPS, SAN, ABS, PC, Nylon 6, PET, PBT, PU, POM, etc.

Text book: Dr. Siddaramaiah. Practicals in Polymer Science, CBS publishers. New Delhi, 2007.

References:

1. K J Saunders. The Identification of Plastics and Rubber, 2nd edition, Chapman & Hall, 1970.
2. E A Collins, J Bares & F W Billmeyer. Experiments in Polymer Science, John Wiley and Sons, New York, 1973.
3. E A Turi. Thermal Characterization of Polymeric Materials, Academic Press, New York, London, 1981.
4. K Joseph. Practicals in Polymer Chemistry. Kulwer Publishing, 1999.
5. M J R Loadman. Analysis of Rubber and Rubber like Polymers, 4th edition, Springer Science and Business Media, 2012.

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PT68L: POLYMER TESTING LAB (0-0-1.5)

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

CO1:	Explain the Significance of the test, detailed procedure for conducting the test and interpretation of results
CO2:	Apply the knowledge of relevant ISO and ASTM standards to polymer testing.
CO3:	Demonstrate the operation of different testing equipments.

List of Experiments:

1. Determination of Tensile properties of thermoplastic plastics as per ASTM standards.
2. Determination of Flexural properties of thermoplastic plastics as per ASTM standards.
3. Determination of Heat Distortion Temperature (HDT) of thermoplastic plastics as per ASTM standards.
4. Determination of Vicat Softening Temperature (VST) of thermoplastic plastics as per ASTM standards.
5. Determination of Izod and Charpy Impact Strength of thermoplastic plastics as per ASTM standards.
6. Determination of (a) Breakdown Voltage and (b) Dielectric Strength of thermoplastics.
7. Determination of Tensile properties of rubbers as per ASTM standards.
8. Determination of (a) Specific gravity of molded rubber specimen (b) Durometer Hardness of rubbers and plastics.
9. Determination of Abrasion Resistance of Rubbers
10. Determination of Flex-Fatigue of molded Rubber specimens.
11. Determination of Rebound Resilience of rubbers.
12. Determination of Carbon Black Content in Polymers by TGA (Demonstration)
13. Determination of loss modulus, storage modulus and tan delta of thermoplastics by DMA (Demonstration).
14. Determination of flammability of material.

15. Determination of Electrical properties using LCR meter.
Text book: Vishu Shah, Handbook of plastics testing technology, John Wiley, NewYork,2007
References: 1. Relevant ASTM standards for testing methods. 2. Polymer Testing Lab Manual (Department of PST).

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G16PS01: GRAPHENE-BASED NANOCOMPOSITES FOR ENERGY HARVESTING/ STORAGE APPLICATIONS (GIAN course) (2-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain synthesis of 2D and 3D graphene by different methods and their nanocomposites	
CO2:	Explain graphene based Energy storage and conversion device fabrication	
Course Content:		
Unit 1	**Fabrication of smart materials based on graphene and their application for Energy Storage :**Synthesis of two-dimensional graphene by different methods: hydrothermal and chemical vapour deposition method; Large-scale synthesis of graphene towards industrial purposes - energy storage and conversion system; Heteroatom (nitrogen and sulphur) doped graphene - Synthesis methods with perfect network; Boron doped graphene and synergistic features - High temperature applications; Synthesis methods of hetero-atom doped graphene and their structural properties; Three dimensional graphene networks: optimization of parameters such as gas flow rate, temperature and reaction time; Preparation of 3D nano network: graphene aerogels, graphene-metal network, graphene-carbon nanotubes assemblies and graphene-polymeric nanocomposites; Fabrication of 3D graphene based nanocomposites - towards energy storage devices super capacitors and Li-ion batteries; and Fabrication of Graphene based supercapacitor devices; Electrochemical performance of supercapacitor (symmetric and asymmetric) devices; Design and techniques involved in supercapacitor device fabrication; Graphene and its nanohybrids towards lithium ion batteries; Fabrication of lithium sulphur and lithium air batteries; High efficient, cost-effective, light weight battery devices	**10h**
Unit 2	**Energy storage and conversion device fabrication and commercialization:** Covalent polymer functionalization of graphene sheets and its electrochemical performance; Graphene-conducting polymer composite preparation and fabrication of energy device; Novel polymer-graphene composites and thin films; Graphene-sulfonated polymer membranes- Fabrication of polymer-graphene membrane electrodes for fuel cells; Control of membrane thickness and fuel cell performance; Graphene-metal nanohybrids- Synthesis and properties; Fabrication of high	**10h**

	efficient electrodes for fuel cells and solar cells; Replacement of graphene metal nanohybrids with existing conventional platinum electrodes; Three-dimensional graphene based nanocomposites- mechanical, electrical and thermal properties; Three-dimensional graphene nanocomposite in modern electronics; Three-dimensional graphene based nanocomposite towards porous architecture. Light weight, efficient and economical approach towards modern electronics; Industrial applications of graphene electrodes- hybrid power systems, energy storage automotive and electronic gadgets; Evaluation and promising breakthroughs of next generation hybrid energy devices.	

Text book:

1. Graphite, Graphene,and their polymernanocomposites: Edr. Prithu Mukhopadhyay and Rakesh K. Gupta, CRC Press Taylor & Francis Group, NW, 2013.

References:

1. Graphene as a Material for Solar Cells Applications, M. Czerniak-Reczulska, A. Niedzielska, A. Jędrzejczak, Advances in Materials Science, 15 (4), 67–81, (2015).
2. Ghavanini F.A., Theander H., Graphene feasibility and foresight study for transport infrastructures; Chalmers Industriteknik, 2015.
3. Santanu Das, Pitchaimuthu Sudhagar and Yong Soo Kang, Wonbong Choia; Graphene synthesis and application for solar cells; J. Mater. Res. 2013.
4. Markvart T., Castaner L., Solar Cells: Materials, Manufacture and Operation; Elsevier, Oxford 2005
5. Graphene-based Energy Devices, A. Rashid bin Mohd Yusoff (Editor), John Wiley & Sons, Inc., 2015.
6. Graphene-based polymer nanocomposites, Jeffrey R. Potts, Daniel R. Dreyer, Christopher W. Bielawski , Rodney S. Ruoff, Polymer**,** 52, (1), 2011, 5–25
7. Recent advances in graphene based polymer composites, T Kuilla, S Bhadra, D Yao, NH Kim, S Bose, JH Lee, Progress in polymer science 35 (11), 1350-1375.
8. Chemical functionalization of graphene and its applications, T Kuila, S Bose, AK Mishra, P Khanra, NH Kim, JH Lee, Progress in Materials Science 57 (7), 1061-1105

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VII Semester

PT710: RUBBER PRODUCT MANUFACTURING (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain various rubber processing techniques used to manufacture rubber products	
CO2:	Select suitable materials and design/ develop rubber compound as per the requirements	
CO3:	Explain different unit operations involved in various rubber product manufacturing and select suitable manufacturing method	
CO4:	Assess the quality of the products using conventional and advanced testing facilities/ methods	
Course Content:		
Unit 1	Different vulcanization techniques, and review of molding, calendering and extrusion processes, Moulded items like seals, gaskets, Coated Fibres and calendered sheething, auto components, Extruded items like tubing, weather strip.	**10h**
Unit 2	Belting – Conveyor, Transmission & V-Belt, Timing belts Hose – Hand made and braided Footwear –Sole manufacturing, microcellular, Unit Sole, Resin Rubber sole, hand-built footwear & DVP/DIP Cables – Insulation and sheath, curing technique, flame resistant non chlorinated (FRNC) and Low Smoke Insulation (LSI)	**10h**
Unit 3	Rubber to Metal bonded components, Rubber Roller Adhesives (pressure sensitive adhesives, solvent and solution based adhesives) Latex Products – Dipped goods, Thread & Foam (Dunlop and Thalalay process)	**10h**
Unit 4	Stress/ Strain Properties- Tensile properties, Tear strength, Compression set under constant stress/ strain, Creep and Stress relaxation, Hardness (shore hardness and IRHD), Abrasion resistance, Effect of environment and ageing of rubber; swelling, oxidative ageing and ozone cracking tests.	**10h**
Unit 5	Dynamic properties (Determination of loss modulus), Determination of rebound	**10h**

	resilience, heat build up by Goodrich flexometer, Flex fatigue: (Determination of crack initiation and crack growth by the De Mattia), Failure in rubber fabric composite using ross flexmeter, Adhesion/Bond testing (Rubber to metal and rubber to fabric adhesion) – peel test, shear test.	

Text book: Rubber Products Manufacturing Technology Ed. By Anil K Bhowmick, Malcolm M.Hall and Henry A.Benarey, Marcel Dekker Inc., New York, 1994.

References:

1. Brendan Rodgers (Edr), Rubber compounding: Chemistry and Application, Marcell Dekker Inc., NY, 2004.
2. Relevant ASTM Standards
3. Sadhan K. De and Jim R. White (Edr), Rubber Technologist's Handbook, Rapra Technology Limited, UK, 2001.
4. R.P.Brown, Physical testing of rubber, Applied Science Publishers Ltd. London, 1979.
5. Maurice Morton (Ed.), Rubber Technology (3rd Edn.), Van Nostrand Reinhold Co., N.Y.1987.

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PT720: POLYMER RECYCLING (4:0:0) **Course Outcomes:** Upon successful completion of this course, the students will be able to		
CO1:	Explain the need and benefits of polymer recycling, collection and sorting methods for the given waste.	
CO2:	Explain primary and secondary recycling aspects.	
CO3:	Explain tertiary and quaternary recycling routes for value addition.	
CO4:	Discuss the recycling principle and uses of commingled waste and thermosets.	
CO5:	Explain the methods and techniques of rubber recycling.	
Course Content:		
Unit 1	**Introduction:** need for polymer recycling, benefits of recycling, terminologies involved in recycling technology; coading and labelling; organisations involved in promoting polymer recycling. **Collection and Separation**: collection methods, material recovery facility (MRF), continuous separation techniques, cyclone separator, eddy current separator, magnetic separators, triboelectric separator, optical and manual sorting.	**10h**
Unit 2	**Primary / secondary recylcing (mechanical recycling):** Stages of recycling (pre sorting, size reduction, separation: separation of nonplasstcs, light contaminants, plastc-plastc separation. Cleaning and conversion into products) **Some case studies**: Polyolefins, Polystyrene, PVC, Acrylics. Recycling of engineering plastics - PET, PBT, ABS, Nylons, Polyacetals, PC, PPO.	**10h**
Unit 3	**Tertiary recycling:** Modes of decomposition, Wet process (PET: glycolysis, methanolysis, hydrolysis, PMMA: Catalytic cracking, PU: glycolysis, hydrolysis and alcoholysis, Nylon: Hydrolysis), Dry process (Pyrolysis) and Gasification. Catalytic cracking of polyolefins, Reactors used in feedstock recycling (Fluidized bed reactor and rotary kiln reactor, salt or lead bath reactor, extruder, Autoclaves, stirred tank reactors, tubular reactors), **Quarternary recycling/ Energy recovery/ Incineration**	**10h**
Unit 4	**Comingled plastics recycling:** Problems related to comingled plastics, methods	**10h**

	used to recycle, Applications (Lumbers, auto parts etc.,) **Recycling of thermoset waste:** Problems in recycling thermoset waste, recycling technologies (Mechanical, thermal and chemical recycling process). Uses of recyclates.	
Unit 5	**Rubber Recycling**: **Crumb Rubber** (Grinding methods: ambient grinding, cryogenic grinding, wet grinding, characterization of powdered rubber, modification of ground rubber, effect of ground rubber on rheological, curing, mechanical properties, applications of ground rubber) **Reclaimed rubber:** Devulcanization tecxhniques: Ultrasonic devulcanization, Chemical devulcanization, Thermal devulcanization, Chemomechanical, thermochemical and thermomechanical techniques, compounding with devulcanized rubber, properties and applications of reclaimed rubber **Pyrolysis of waste rubber:** conversion of used tire to carbon black and oil.	**10h**

Text books:

1. R J Ehirg. Plastics Recycling: Products and Processes, Carl Hanser Verlag, Munich, Germany, 1992.
2. G Akovali, C Bernardo, J Leidner, L A Utracki and M Xantho. Frontiers in the Science and Technology of Polymer Recycling, 2nd edition, Spriger Science and Business media, 2013.

References:

1. N. Mustafa. Plastics Waste Management: Disposal, Recycling and Reuse, Marcel Dekker, Inc. New York. 1993.
2. J Brandrup, M Bittner, W Michacli, G Menges. Recycling and Recovery of plastics. Hanser, Munich, Germany, 1996.
3. A. L. Andrady. Plastics and the Environment, John Wiley and Sons, USA, 2003. (Chapters 13, 14 and 15).
4. V L Shulman. Tyre Recycling. RAPRA publications, UK, vol 15(7), 2004.
5. K. Sadhan, De Avraam, I. Isayev, K Khait. Rubber Recycling, Taylor & Francis Group,

New York, 2005.

6. J. Scheirs and W. Kaminsky, Feeds stock Recycling and Pyrolysis of Waste Plastics: Converting Waste Plastics into Diesel and Other Fuels, John Wiley & Sons, USA, 2006.

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PT730: DESIGN OF MOULDS AND DIES (3-1-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the different mould materials, machining operations in mould making and feed system for a particular mould	
CO2:	Explain the different types of cooling and ejection systems used in injection moulds	
CO3:	Select a suitable machine and mould for a polymer component	
CO4:	Design a compression mould for a particular product	
CO5:	Explain the theoretical concepts of extrusion dies and split moulds	
Course Content:		
Unit 1	**Mould making materials:** Different materials used for making molds (in brief), Types of molds: Integer and Bolster, Mold making techniques: Brief introduction about conventional and non conventional mold making techniques. **Injection mould design:** Design of feeding system: Sprue, runners and gates, types of runners and gates, balancing of runners and gates.	**10h**
Unit 2	**Injection mold design continued: Design of cooling system:** Integer and bolster cooling (both core and cavity cooling) **Ejection systems:** Introduction, ejection techniques different types like pin ejection, blade ejection, stripper plate, valve ejection, air ejection, sleeve and stripper ring ejection.	**10h**
Unit 3	**Design of single and multiple cavity two plate injection molds:** (i) Selection of machine (ii) Selection of molds, numerical.	**10h**
Unit 4	**Compression mold design:** Design steps, designing of compression molds: positive, semi positive and open flash molds. Numerical	**10h**
Unit 5	**Designing of undercuts, split molds, cam design:** different types of cam actuation	**10h**

	Design of extrusion dies – pipe dies and film dies: Extrusion dies and tools for thermoplastics: general concepts of die design, analytical flow relationships; flow rates versus pressure, sheet die design, blown-film dies and tooling, pipe and tubing dies, cross head covering dies and co-extrusion dies.	

Text book:

1. Ronald George William Pye, Injection mold design, 4th edition, Longman Scientific & Technical, 2007.

References:

1. Michaeli W, Extrusion Dies. Macmillan,1984
2. E. G. Fisher, Extrusion of Plastics, Newnes-Butterworth, London, England, 1976.
3. R.H.Bebb, Plastics Mould Design. V.1, Compression and Transfer Moulds, Iliffe, London, 1962
4. Dubois and Pribble, plastics mold engineering handbook, Chapman & Hall, 2007

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PT741 TOTAL QUALITY MANAGEMENT (4:0:0) (Elective-2)

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

CO1:	Explain the fundamental principles of Total Quality Management and management philosophies
CO2:	Classify and analyze the quality costs
CO3:	Explain the tools and techniques of quality management
CO4:	Analyze and construct suitable tools and techniques of quality management
CO5:	Explain BIS and ISO standards

Course Content:

Unit 1	Quality, Total Quality, TQM: Introduction-Definition, Basic Approach, TQM frame work, Historical review, Benefits of TQM. Evolution of TQM: Contribution of Quality Gurus-Edward Derming,14points,PDSA cycle, Joseph Juran, Quality trilogy, Crosby & quality treatment, Ishikawa & company wide quality control, Taguchi & his quality loss function.	**10h**
Unit 2	Leadership & Quality Costs: Characteristics of quality leaders, Quality statement, Strategic Planning, Introduction to quality costs, Prevention costs, Appraisal costs, Failure costs, Management of quality costs, Economics total of quality costs& its reduction, Cost benefit analysis.	**10h**
Unit 3	Continuous Improvement: Improvement as problem solving process, W-V model of CI, process control. Reactive Improvement, Standard steps & 7 tools of quality,7 steps, management diagnosis of seven steps, reactive improvement. Proactive Improvement. Introduction, Standard steps, 7 management tools, applying proactive improvement, to develop new product-three stages& nine steps. Benchmarking Definition, Process of Benchmarking, 5S, 3M, PokaYoke.	**10h**
Unit 4	Tools & Techniques in TQM: Kaizen, Re-engineering, Six Sigma, Quality Function Development & Failure Modes Effects Analysis: Introduction to QFD & QFD process, Quality by design, Rationale for implementation of quality by design, FMEA, design FMEA & process FMEA	**10h**

Unit 5	Quality Management Systems: Introduction to different standards Quality management systems, Bureau of Indian standards (BIS), Institute of Standard Engineers(SEI), ISO-9000 series of standards, Overview of ISO-14000.	**10h**

Text book: K. Shridhara Bhat ,Total Quality Management, , Himalaya Publications

References:

1. Dale H. Bester field, TQM, Pearson Education India, ISBN: 8129702606, Edition 03/e Paperback (Special Indian Edition)
2. M. Zairi ,Total Quality Management for Engineering, ISBN:1855730243, Wood head Publishing
3. A New American TQM, four revolutions in management, ShojiShiba, Alan Graham, David Walden, Productivity press, Oregon,1990
4. Gopal K. Kanji and Mike Asher, 100 Methods for Total Quality Management, ISBN:0803977476,Publisher: Sage Publications Inc.: Edition-1
5. H. Lal, Organizational Excellence through TQM, New age pub, 2008.

PT742: ADHESIVE TECHNOLOGY (4-0-0) (Elective-2) **Course Outcomes:** Upon successful completion of this course, the students will be able to -		
CO1	Explain the theories, mechanism, advantages and disadvantages of adhesive bonding	
CO2	Select suitable joint design and surface preparation methods	
CO3	Describe the properties and applications of structural and non structural adhesives	
CO4	Explain the Selection of adhesives for different substrate and effects of environment on adhesives performance	
CO5	Analyze and evaluate different properties of adhesives and explain the applications of adhesives in various industries.	
Course details:		
Unit 1	**Introduction** – Fundamentals of adhesives, Advantages and disadvantages of adhesive bonding, theories of adhesion, Requirements of good bond, mechanism of bond failure, classification of adhesives.	**10h**
Unit 2	**Adhesive bonding process**- Design of joints: Types of stress, factors affecting joint efficiency, Common adhesive joint design- for flat adherends, stiffening joints, cylindrical joints, angle & corner joints, plastic and elastomer joints, wood joints. Surface preparation: Nature of substrate surfaces, Surface treatment, passive & active surface preparation methods.	**10h**
Unit 3	**Structural adhesives**: Epoxies, PF, UF, 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 4	**Environmental properties of adhesives**: Effect on temperature (high & low), humidity & water, Outdoor weathering, chemicals and solvents, vacuum and radiation. **Selection of adhesives:** (a) Factors affecting selection, (b) Adhesives for	**10h**

	metals, (c) Adhesives for plastics, (d) Adhesives for Elastomers, (e) Adhesives for wood and (f) Adhesives for glass	
Unit 5	**Testing and quality control of adhesives** - Tensile test, Peel tests, lap shear test, cleavage test, fatigue test, impact test, creep test, environmental tests and methods of quality control. **Application of adhesives** - In electrical and electronic industry, wood industry, bio adhesive in drug delivery, dentistry and automobile industry	**10h**

Text books:

1. Hanbook of adhesives & Sealants- Ed by Edward M Petrie, Mc Grew-Hill, New York 2000
2. Handbook of Adhesive technology – Ed. By A.Pizzi and Mittal. Marcel Dekker Inc, Newyork 1994

References:

1. Lucas F. M. da Silva, Andreas Öchsner, Robert Adams, Handbook of Adhesion Technology, Springer-Verlag , Berlin Heidelberg., 2011.
2. Charles V. Cagle, Henry Lee, Kris Neville, Handbook of adhesive bonding- Mc Graw` Hill. McGraw Hill, 1973.
3. J. Shields, Adhesives Hand Book, Butterworths & Co,1984
4. R.Houwink and G.Solomon, Adhesion and Adhesives, Elsevier, Amsterdam, London, NY 1965
5. Irving Skeist, Handbook of adhesives, Springer US, 2011

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PT743 : PACKAGING TECHNOLOGY (4-0-0) (Elective-2) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain fundamentals, types and uses of plastics as packaging materials	
CO2:	Explain the different packaging materials, processes involved	
CO3:	Explain the various stages involved in packaging technology	
CO4:	Explain quality control test standards and methods for packaging	
Course Content:		
Unit 1	**Introduction to packaging:** Definitions, need for packaging, properties and forms of packaging materials (wood, metal, glass, paper and plastics). Advantages and disadvantages of plastics packaging applications (foods and beverages, cosmetics and toiletries, medical products, shipping containers, drugs and pharmaceuticals). Selection criteria for packaging materials. **Introduction to plastics being used in packaging industry:** Properties and Applications of Thermosets (PF, UF, Glass fiber reinforced polyesters) Thermoplastics (Polyolefins, PVC, PVDC, PVA, EVA, PS, ABS, Polycarbonate, Cellulose acetate, PET, PTFE, PTFCE, MPVF, Nylon, Ionomers).	**10h**
Unit 2	Processing Techniques of Single Layer and Multilayer Packaging : Lamination techniques wet lamination, dry lamination, thermal or heat lamination (fusion method), wax or hot melt lamination, extrusion lamination (melt lamination), coextrusion process [cast film coextrusion, blown film coextrusion, coextrusion coating, coextrusion lamination, cast sheet coextrusion] Properties and applications of coextruded films/sheets importance of multilayer packaging, machinability of laminates and films.	**10h**
Unit 3	Uses of barrier materials in packaging, measurement of gas transmission rate (WVTR and OTR). Packaging operations: Bottling, canning, wraping, cartoning operations, Form-fill and seal machines.	**10h**
Unit 4	Decorations of plastics packages: Main printing processes such as letter press, flexography, lithography, Gravure, silk screen, ink jet printing, hot die stamping	**10h**

	and gold blocking, Factors affecting the choice of a printing process. Finishing Techniques such as Heat sealing, pressure sealing, adhesive sealing, solvent sealing, ultrasonic sealing etc.	
Unit 5	Evaluation and Testing of Plastics Packages: Introduction, general test methods, heavy duty packages, testing of blown moulded containers, laminates, stack load test, drop test, vibration test unusual test methods, testing of flexible plastic films, on line monitering devices.	**10h**

References:

1. Plastics in Packaging – A.S.Athalye, Mc.Graw Hill publisher, New Delhi 1992.
2. Plastics in Flexible packaging – A.S.Athalye, Multitech publishing Co. 1992, Bombay.
3. A handbook of food packaging – Frank A Paine & Heathek Y. Paine, Blackie Academic & Professional, New York, 1980.
4. Polymer Permeability – Ed. By J.Comyn. Elsevier Applied Sciences.
5. Plastics films – Ed. J.H. Briston Honymann Scientific and Technical Publications U.K.
6. Science and Technology of Polymer films – Vol.2 – Ed. O.J.Sweething.
7. Diffusion Mass Transfer in Fluid Systems (Second Edition)- E.L.Cussler, Cambridge University Press, Cambridge, 1998.

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PT744: PVC TECHNOLOGY (4-0-0) (Elective-2) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain fundamentals of PVC and related compounds.	
CO2:	Explain the elementary principles and Formulations for PVC based products.	
CO3:	Explain compounding of PVC materials.	
CO4:	Explain processing PVC materials and its commercial importance.	
Course Content:		
Unit 1	**Introduction:** PVC general Terminology and Relevant Definitions, Early history and Development of PVC. Outline of the PVC sector of the plastics industry. **PVC Resins: Production:** Manufacture of VCM, Manufacture of PVC, PVC co-polymers, chemically modified PVC, Syndiotactic PVC, Chlorinated PVC, PVC grafts, Acrylic graft; EVA grafted PVC, X-linked PVC, PVC blends and alloys.	**10h**
Unit 2	**Elementary Principles of PVC Formulation:** The components and basic types of PVC formulation, formulation Costing, main general considerations in the selection of principal formulation components, Nature and Characteristics of individual components of a formulation, PVC polymer, heat stabilizers, Plasticizers lubricants, Polymeric modifiers, fillers, colourants etc., interactions and mutual effects of formulations components. **Examples of basic formulation :** Film and sheeting, calendared plasticised vinyl/asbestol flooring, pipe and tubing, cable covering and insulations, gramophone records, blow molded bottles, UPVC pipe fittings, paste formulations.	**10h**
Unit 3	**Compounding of PVC:** Compounding machines, intensive dry mixers, internal intensive batch mixers, Continues mixer, Two roll mills, Single screw extruder, Compounder extruder, Twin screw extruder.	**10h**
Unit 4	**Testing:** Testing of PVC Resin; K Value, Bulk density, Plasticizer absorption, partical size distribution, powder flow etc. Testing of PVC Compounds : Specific gravity, Bulk density, Water absorption, hardness, static heat stability, Brabender gelation and degradation time, etc.	**10h**

Unit 5	**Applications of PVC:** Main applications of primary PVC products, Composite products, PVC fibers and fiber products, Miscellaneous products and applications.	**10h**
Text Book: PVC Technology , 4th Edition, W.V. Titow, Elsevier App Sc. Publishers, London		

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PT75L: CAD LAB (0-0-1.5)		
Course outcomes: Upon successful completion of this course, the students will be able to-		
CO1:	Explain basic concepts of 2D drafting and solid modeling.	
CO2:	Generate 2D drawing of machine elements and its assembly.	
CO3:	Apply the knowledge of 2D drawing to generate 3D models.	
CO4:	Design and assemble injection molds.	
Course Contents:		
Exercise 1	Introduction to 2D drafting Line diagrams of the following components with standard dimension 1. screw threads 2. Nuts, locking nuts and bolts 3. Couplings – split – muff, flanged, solid flanged, protected type flanged coupling. 4. Socket and spigot joint 5. Gears – Drawing of toothed profiles – Spur, gear, worm and worm wheel	**6h**
Exercise 2	Assemblies of the following components should be covered 1. Stuffing box – vertical type 2. Bearing – Plummer block and foot step bearing 3. Valves – stop valve, Rams bottom safety valve, feed check valve.	**6h**
Exercise 3	Introduction to 3D solid modeling	**9h**
Exercise 4	Drawing of feeding system, sprues, runners, gates, runners and gates for balanced system, cooling system and ejection system for injection molds, Drawing of integer core and cavity, insert and bolster core and cavity	**6h**

Exercise 5	Assembling of two plate injection mold	**6h**

Text Books:

1. Machine drawing, N.D. Bhatt & V.M. Panchal, Chartar Publishing House, Anand, India
2. Injection mould design - R.J.W. Pye, George Goodwin Limited, London.

References:

1. Auto CAD 2002 Bible - Ellen Finkelstein, IDG books India (P) Ltd., New Delhi.
2. Computer Aided Design & Manufacturing - CB Besant & CWK Lui - east west, New Delhi.

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PT76P: RESEARCH METHODOLOGY (2-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Understand and Explain the need/ types of research, Intellectual property rights and citations;	
CO2:	Conduct literature survey, identify gap and define research problem;	
CO3:	Design the research work and utilize statistical tools for collection, analysis and reporting the research data;	
CO4:	Adopt ethics and Communicate the research findings effectively;	
CO5:	Adopt life-long research for being sustainable in competitive society through innovative contributions.	
Course Content:		
Unit 1	**Introduction:** Definition of research; objectives, characteristics and significance of research; methods vs methodology. Types of research: Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical, and other types. Research Process flow diagram. **Intellectual Property**- Publications, Patents, Trademarks, Geographical Indications, Industrial Designs, Copyright and related Rights. **Citations,** bibliography & referencing.	**5h**
Unit 2	**Research Formulation:** Literature Survey: source of information- internet as source (scholarly articles- patents, journal articles, text books). Critical literature review & Identifying the gap. Defining and formulating the research problem; Development of working hypothesis.	**5h**
Unit 3	**Research Design:** features and types. Design of sample surveys. **Data Collection and Analysis-** Execution of the research, observation and collection of data, primary and secondary source of data, Sampling techniques, Data Processing and Analysis strategies. **Statistics in Research-** Measurements & Scaling, types of statistics, measurement of internal/ central tendency, dispersion, skewness, kurtosis, relationships; use of chi-square, ANOVA, Regression analysis. Hypothesis-testing flow chart.	**5h**

Unit 4	**Report writing**- Types & steps. Structure and components of scientific reports & thesis, Language of typical reports, Layout, Illustrations and tables. Effective communication: oral presentation & use of visual aids, preparation of slides; usage of various tools. **Ethics** & Plagiarism;	**5h**
Unit 5	**Innovation;** Criteria for good research; Problems encountered by researchers; Proposal Writing; Funding agencies; R&D projects; Publishing in peer reviewed Journals (research index) & Conference; Quality research- Interdisciplinary & Collaborative works for useful output. Research trends; Research involving Polymers.	**5h**

Text Book: Kothari, C.R., Research Methodology: Methods and Techniques. New Age International, 1990 (418p).

References:

1. Garg, B.L., Karadia, R., and Agarwal, An introduction to Research Methodology, RBSA Publishers, U.K., 2002.
2. 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.
10. http://nptel.ac.in/courses/113105028/38.
11. http://www.wipo.int/about-ip/en/.

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VIII Semesters

PT810: INDUSTRIAL ENGINEERING AND MANAGEMENT (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the structure and working of business organization.	
CO2:	Interpret and analyze annual financial report of an industrial organization	
CO3:	Construct, interpret and use cost calculations as part of the decision making with the budget concepts.	
CO4:	Explain the concepts of quality control and inventory control	
CO5:	Explain the working of HR department, concept of business ethics and compose report writing.	
Course Content:		
Unit 1	Production and productivity, organization-concept, important elements, principles of organization like-division of labor, scalar and functional processes, structure, span of control, delegation etc., types of organization, organization and management development. Industrial ownership-Types of ownership	**10h**
Unit 2	Financial management: Types of capital, Sources of finance, Financial statements:- Balance sheet and Income statement, Ratio analysis: Meaning of Financial Ratio, Standards of Comparison, Differences between Analysis and Interpretation of Financial Statements ,Types of Ratios: Liquidity Ratios, Leverage Ratios, Activity Ratios, Profitability Ratios, Limitations of Ratio Analysis, Summary of Ratios and their Purpose-and Related Numerical's	**10h**
Unit 3	Cost Estimation: Estimation, importance, aims of estimation, functions, differences between estimation and costing. Elements of cost, analysis of over head expenses, Costing –Machines and tools, Estimation of machining time, and costing. Deprecation – Meaning, methods and comparisons**.**And Related Numerical's. Budget and budgeting and Related Numerical's.	**10h**
Unit 4	Inspection and quality control: Definition and concept, SQC-Basic fundamentals,	**10h**

	normal distribution, process and machine capability, testing and its significance, sampling inspection, control charts.- and Related Numerical's Inventory control and management- introduction, objectives, functions, EOQ, inventory models-Simple and EOQ with stock out, ABC analysis and Related Numerical's	
Unit 5	Human resource management, Professional and business ethics, professional communication and report writing.	**10h**

Text book: 1.O.P.Khanna and A.Saroop, Industrial Engineering and Management, Dhanpat Rai publications(p) Ltd, Reprint, 2001.

References:

1. Koontz O Donel, Management in engineering: principles and Practice:, Second edition, Prentice Hall,2012
2. Stephen.P.Robbins and Mary Coulter, Management, , 9th Edition, Prentice Hall,2008.
3. Heinz Weihrich and Harold Koontz, Management,Tata Mc Graw Hill, 2001.
4. Jack Sweeting , Project Cost Estimating: Principles and Practice, , Institute of chemical engineers, UK, 1997
5. T. R. Banga, S. C. Sharma, N. K. Agarwal, Industrial Engineering and Management Science, Khanna, 5th Ed, 2007
6. GBS Narang and V.Kumar, Production and Costing, , Khanna publishers, 1978.

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PT821: PAINTS TECHNOLOGY (4-0-0) (Elective-3)		
Course outcomes: Upon successful completion of this course, the students will be able to-		
CO1:	Explain synthesis, formulation, properties and applications of industrial paint resin.	
CO2:	Describe properties & applications of pigments and preparation of pigment dispersion	
CO3:	Select suitable surface preparation, paint application & curing methods.	
CO4:	Analyze and evaluate different properties of painted panels.	
CO5:	Explain applications of paints in various industries	
Course details:		
Unit 1	**Industrial paint resins**- Synthesis, properties, formulations and applications of paints and coatings of the following resins need to be discussed: Alkyds and polyesters, phenol formaldehyde, silicone resin, epoxy resin, chlorinated rubber, polyurethanes and acrylic resins.	**10h**
Unit 2	**Pigments & pigment dispersion**- organic and inorganic pigments, Manufacturing and properties of pigments, Factors affecting dispersions, preparation of pigment dispersion, grinding equipment,	**10h**
Unit 3	**Painting processes** (a) Surface preparation: mechanical cleaning, solvent cleaning, alkali cleaning, and acid pickling. Chemical conversion treatment. (b) Paint application: mechanism of film formation Applying processes: brushing, dip coating and flow coating, curtain coating, roller coating and spray painting. (c) Curing- Physical, chemical and oxidative curing. Factors affecting coating properties	**10h**
Unit 4	**Testing and evaluation of paints** - Mechanical, optical, flammability and environmental properties	**10h**
Unit 5	**Application of paints** - Appliance finishes, automotive finishes, coil	**10h**

	coating, can coating, marine coating and aircraft coating	

Text Book:

1. Swaraj Paul, Surface coatings: Science & Technology, J. Wiley, 1996

References:

1. R Lambourne and T R Strivens ,Paint & Surface coatings. Theory and practice. Elsevier, 1999
2. Charles A Happer , Handbook of Plastics, Elastomers and Composites, McGraw Hill Professional, 2002
3. M. Gopalarao & Marshall Sittig, Dryden's out lines of chemical technology-For the 21st centuary, East west press Pvt. Ltd, New Delhi, 1973.

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PT822: BIOMATERIALS (4-0-0) (Elective-3) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Describe and compare classes and properties of biomaterials and their applications in medicine.	
CO2:	Predict host response to various classes of biomaterials with regard to biocompatibility, function, and failure.	
CO3:	Illustrate cell-biomaterial and tissue-biomaterial interactions.	
CO4:	Explain methods of biomaterials processing and characterization.	
CO5:	Select materials and optimize material properties for enhanced function and biocompatibility.	
Course Content:		
Unit 1	Introduction: Definition of biomaterials, requirements of biomaterials, classification of biomaterials, Comparison of properties of some common biomaterials. Effects of physiological fluid on the properties of biomaterials. Biological responses (extra and intra-vascular system). Surface properties of materials, physical properties of materials, mechanical properties.	**10h**
Unit 2	Polymeric implant materials: Polyolefins, polyamides, acrylic polymers, fluorocarbon polymers, silicon rubbers, acetals. (Classification according to thermosets, thermoplastics and elastomers). Viscoelastic behavior: creep-recovery, stress-relaxation, strain rate sensitivity. Importance of molecular structure, hydrophilic and hydrophobic surface properties, migration of additives (processing aids), aging and environmental stress cracking. Physiochemical characteristics of biopolymers. Biodegradable polymers for medical purposes, Biopolymers in controlled release systems. Synthetic polymeric membranes and their biological applications.	**10h**
Unit 3	Composite implant materials: Mechanics of improvement of properties by incorporating different elements. Composite theory of fiber reinforcement (short and long fibers, fibers pull out). Polymers filled with osteogenic fillers (e.g. hydroxyapatite). Host tissue reactions.	**10h**

	Biocompatibility and toxicological screening of biomaterials: Definition of biocompatibility, blood compatibility and tissue compatibility.	
Unit 4	Biocompatibility & toxicological screening of biomaterials, Toxicity tests: acute and chronic toxicity studies (in situ implantation, tissue culture, haemolysis, thrombogenic potential test, systemic toxicity, intracutaneous irritation test), sensitization, carcinogenicity, mutagenicity and special tests. Sterilisation techniques: ETO, gamma radiation, autoclaving. Effects of sterilization on material properties.	**10h**
Unit 5	Testing of biomaterials/Implants: In vitro testing (Mechanical testing): tensile, compression, wears, fatigue, corrosion studies and fracture toughness. In-vivo testing (animals): biological performance of implants. Ex-vivo testing: in vitro testing simulating the in vivo conditions. Standards of implant materials. biodegradation, bioerrosion, and biocompatibility.	**10h**

References:

1. J B Park, Biomaterials - Science and Engineering, Plenum Press , 1984.
2. Sujata V. Bhat, Biomaterials, Narosa Publishing House, 2002.
3. Jonathan Black, Biological Performance of materials, Marcel Decker, 1981
4. C.P.Sharma & M.Szycher, Blood compatible materials and devices, Technomic Publishing Co. Ltd., 1991
5. Piskin and A.S. Hoffmann, Polymeric Biomaterials (Eds), Martinus Nijhoff Publishers. (Dordrecht. 1986)
6. Eugene D. Goldbera , Biomedical Polymers, Akio Nakajima
7. A . Rembaum & M. Shen, Biomedical Polymers, Mercer Dekkar Inc. 1971
8. L. Hench & E. C. Ethridge, Biomaterials - An Interfacial approach

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PT823: MEMBRANE TECHNOLOGY (4-0-0) (Elective-3) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Identify and describe the unit operations associated with membrane technology	
CO2:	Describe the polymeric materials used for membrane synthesis	
CO3:	Explain the different membrane models and mechanisms of separation processes	
CO4:	Describe the industrial applications of membrane technology.	
CO5:	Explain the concept of controlled drug release	
Course Content:		
Unit 1	**Introduction:** Gas permeation, Liquid and Vapor Permeation, Reverse Osmosis, Ultrafiltration, Separations Processes.	**10h**
Unit 2	Introduction to polymer membranes, scope and application, methods of preparation of polymer membranes and their structure.	**10h**
Unit 3	**Molecular Diffusion:** Solutions to Diffusion Equations, Steady State Solution, Time Lag Technique, Equilibrium Sorption, Temperature Dependence, Theories of Diffusion and Relation to Free Volume, Penetrant Localization, Glassy Polymers and Dual Mode Transport, Anomalous Transport of Vapour in Glassy Polymers.	**10h**
Unit 4	**Membrane Separations :** Introduction, Osmosis and Reverse Osmosis, Irreversible Thermodynamics, The preferential Sorption Capillary Flow Mechanism, Solution-Diffusion Model, Ultrafiltration, Pre- selectivity, Stage Calculations, Membrane Design, Gas Separations.	**10h**
Unit 5	**Controlled Release Applications**: Introduction, Transdermal Drug Delivery (TDD) System, Theoretical Considerations, Drug Delivery with Silicon Elastomers, Diffusion Cell, Evaluationg the Hydrodynamic Characteristics.	**10h**
Text book: Diffusion In and Through Polymers – Wolf R.Vieth Hanser Publishers, New York, 1991.		

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PT824: SMART MATERIALS (4-0-0) (Elective-3) **Course Outcomes: Upon successful completion of this course, the students will be able to-**		
CO1:	Explain physical principles underlying the behavior of smart materials.	
CO2:	Explain fundamentals of nanomaterials and their role	
CO3:	Explain basic principles and mechanisms of the stimuli-response for the most important smart materials.	
CO4:	Explain physical principles underlying the behavior of electro-active organic compounds	
CO5:	Explain engineering design, principle and production of smart materials	
Course Content:		
Unit 1	Introduction to materials -Classes of materials – Smart/intelligent materials – Functional materials – Diverse areas of intelligent materials – primitive functions of intelligent materials – Examples of intelligent materials – Materials responsive to thermal, electrical, magnetic, optic, stress fields, Biocompatible materials and bio-Mimitics Amorphous and glassy materials – Structure – Preparation methods and novel properties – Shape memory alloys – working mechanism – pseudo elasticity – applications – Nickel-Titanium (Nitinol) alloys – Material characteristics of Nitinol – Introduction to Micro Electro Mechanical Systems (MEMS) – Silicon, porus Silicon and silicon oxide based MEMS –Fabrication of piezoelectric and piezo-resistive MEMS materials – Application to micro-actuators and microaccelerometers	**10h**
Unit 2	Nano-structured materials Definition – Types – preparation and characterization techniques – Size effects on various properties – Carbon nanotubes – silicon and silicon oxide nano wires – Mechanical (hardness, ductility, elasticity), optical and electrical properties of nano tubes and nano wires – quantum wires and quantum dots	**10h**
Unit 3	Electroactive Organic Compounds - Moles and Molecules; Acids and Bases; Ions; Solvents; Functional Groups; Aromatic Compounds; Conductive Polymers; Buckyballs and Nanotubes; Fullerenes ; Carbon Nanotubes ; Piezoelectricity,	**10h**

	Pyroelectricity and Ferroelectricity; Basic Principles; Organic Piezoelectric, Pyroelectric and Ferroelectric Compounds; Thin Film Processing and Device Fabrication	
Unit 4	Established Deposition Methods - Spin-Coating; Physical Vapour Deposition; Chemical Vapour Deposition; Electrochemical Methods, Sol–Gel Processing Molecular Architectures - Langmuir–Blodgett Technique; Chemical Self-Assembly; Electrostatic Layer-by-Layer Deposition Nanofabrication – Photolithography; Soft Lithography Techniques; Scanning Probe Manipulation; Dip-Pen Nanolithography Plastic Electronics – Introduction; Organic Diodes - Schottky Diode; Ohmic Contacts Metal–Insulator–Semiconductor Structures - Idealized MIS Devices; Organic MIS Structures	**10h**
Unit 5	Organic Light-Emitting Displays - Device Efficiency; Methods of Efficiency Improvement; Full-Colour Displays; Electronic Paper Photovoltaic Cells - Organic Semiconductor Solar Cell, Dye-Sensitized Solar Cell; Luminescent Concentrator. Other Application Areas - Conductive Coatings; Batteries and Fuel Cells; Xerography Chemical Sensors and Actuators- Sensing Systems; Chemical Sensors- Calorimetric Gas Sensors, Electrochemical Cells; Gas Sensors; Acoustic Devices; Optical Sensors Physical Sensors and Actuators - Touch Sensors; Polymer Actuators; Lab-on-a-Chip; Smart Textiles and Clothing.	**10h**

References:

1. Mukesh V.Gandhi and B.S.Thompson, Smart materials and structures, Chapman & Hall, London, 1992.
2. T.W.Duerig, K.N.Melton, D.Stockel and C.M.Wayman, Engineering aspects of shape memory Alloys,Butterworth-Heinemann,1990

3. Sorab K. Gandhi, Fabrication Principles of VLSI, John Wiley, 1996
4. Charles P.Poole and Frank J Owens, Introduction to nano technology, Wiley Interscience, 2003.
5. Tapan Chatterji, Colossal magnetoresistive manganites, Kluwer Academic Publishers, 2004
6. Malcolm E.Lines and Alastair M.Glass, Principles and applications of Ferroelectrics and Related materials, Oxford University Press, 2001
7. Inoue and K.Hashimoto, Amorphous and Nanocrystalline Materials: Preparation, Properties and Applications, Springer Verlag

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PT831: TIRE TECHNOLOGY (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain basic concepts of tire and importance of various departments of tire industry.	
CO2:	Explain the functions of raw materials used and formulate compounds to meet specific requirements for tire components	
CO3:	Explain the importance of process parameters and solve the problems associated with tire manufacturing processes	
CO4:	Describe the steps involved in the production of tire components	
Course Content:		
Unit 1	(a) **Introduction:** tire terminologies, function of a tire, classification of tire, anotomy of tire, tread patterns and its importance, sidewall markings and its importance, advantages of radial tire, A birds eye view of the Tyre manufacturing process industries. (b) **Major processing sections** of a Tyre Industry – An explanation of different departments and their function and relation to other departments	**10h**
Unit 2	(a) **Compound design and prepartion for mixing** : Mixing operation- open mill & internal mixing parameters Testing and despatch of mixes:, responsibility of mixing department. Basic quality control and mill room control laboratory, recent trends in compound design (ecofriendly). **(b) Textiles in Tyre Industry** : Cotton, Rayon, Nylon & steel cords, styles and construction, Basics of rubber – Fabric bonding necessities of stronger fabrics leading to bonding methods developments. Wet & dry bonding systems – dip and hot stretch proces for Nylon. RFL-VP latex systems – and parameters of dip & hot stretch process for Nylon surface treatment for polyesters & glass fabric. Metal coating for steel cord. Recent developments in Radical Tyre fabrics – Aromatic Nylons (Kevlar) , Aralon (Nylon/aramid) and other special fabric reinforcement systems and their use. Testing of dipped fabrics 'U', 'H' and other tests. Dip pick up and the relation to adhesion etc	**10h**

	(c) Calendering process : 3 and 4 roll calenders, Skimming & frictioning process preparation of bead wrap and chafer and sqeezee using 3 roll calenders. Advantages and disadvantages of 3 roll and 4 roll calenders, process control aspects – economics. Defects of calendered fabrics and their remedies. Parameters for scrap control in fabric processes in the tyre industry requirement of total quality control involving fabric supplier's dipping, calendering and bias cutting operations	
Unit 3	(a) **Tread Extrusion** : Basic concepts of Extrusion. Die swell & shrinkage phenomenon – effect of compounding parameters on these phenomenon. Die design and theoritical calculation of tread weight. Effect of viscosity & temperature on extrusion. Dimensions and weight control extrusion operation parameters like feeding rate, screw speed, take off conveyor speed on tread extrusion. Extruded tread profile – critical dimensions. Dual extruder – Cap & base concept relation to tyre wear parameters like tread wear, heat build up etc. (b) **Bead construction** : Cross head extruder wire coating process. Horizontal and vertical laying of coated wire, concept of hexagonal bead making, Apex preparation on extruder and profile calender Bead wrapping and flipping operations. Multiple bead concept	**10h**
Unit 4	(a) **Bias cutting and pocket making** : Bias angle specification and the significance, Width and angle adjustments splicing and identification. Bias plies pocket 3-3-2, 4-4-2, 2-2-2 ply constructions, Defects of pockets - wrong identification, over splicing, wrinkles, parallel plies (b) **Tyre building :** Tyre building inputs: Inner liners, plies, beads, tread, side wall and gum strips – their inspection Drum inspection for drumset, drum circumference Significance of parameters for tyre building. Size making on finished tyre and the relation to building specifications. Tyre building specifications sequence of building. Intermitant consolidation use of various cements and gum strips. Importance of the state of the Art Technology. Quality control in tire building. (c) **Green Tyre preparation & curing**: painting – Awling, Bag-o-matic and Air	**10h**

	bag curing – mold lubrication- Bladder assembly bead curing rings, Services to the Bag-o-matic presses, Cure cycle, Determination of optimum cure of tyres by thermocouple study. Economics of curing, post cure inflation of Nylon tyres, cured tyre inspection. Defects of tyres – Tyre classification for defects – causes and discussions	
Unit 5	(a) **Retreading of tires**: Need for retreading, Tyres for retreading, Hot and cold process of retreading **(b) Tire engineering concepts** – construction, Principles of tyre profiles and mould design**,** Basics on bladder design, drum design, tube design **(c) Tire testing**: destrutive and non distructive tests **(d)** Recent trends in manufacturing technology: C3M (Michelin), IMPACT (Goodyear), MIRS (Pirelli), BIRD (Bridgestone), Continental	**10h**
Text book: Tyre Technology – F.J.Kovac, 1973, Good Year Tire & Rubber Company		

References:

1. C.M. Blow, Rubber Technology and manufacture, Butter Worths, London, 1982.
2. Maurice Morton (Ed.), Rubber Technology (3rd Edn.), Van Nostrand Reinhold Co., N.Y.1987.
3. Brendan Rodgers (Ed), Rubber compounding: Chemistry and Application, Marcell Dekker Inc., NY, 2004.

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PT832: THERMOPLASTIC ELASTOMERS (4-0-0) **Course Outcomes:** Upon successful completion of this course, the students will be able to-		
CO1:	Explain the structure-property relationships, morphology and applications of different thermoplastic elastomers.	
CO2:	Describe different methods used for the production of TPEs	
CO3:	Explain about various additives and processes used for thermoplastic elastomers.	
CO4:	Develop TPE compounds to meet desired product specifications.	
Course Content:		
Unit 1	**Introduction:** Definition, history and growth. Advantages and disadvantages over conventional plastics & rubbers. Introduction to the two phases/ components/ blocks generally present in TPEs and their role or influence on material property. Wide service temperature range & transitions in TPEs compared. Classification of TPEs (blends/ copolymers; commodity/ engineering; family; etc). Brief introduction to the six classes of TPEs.	**10h**
Unit 2	Commercial Production/ Synthesis, structure, morphology, property/ composition relationship, compounding, processing and commercial applications of: • Styrenic Thermoplastic Elastomers (SBCs- SBS, SIS, etc). • Copolyester Thermoplastic Elastomers (ether & ester based).	**10h**
Unit 3	Commercial Production/ Synthesis, structure, morphology, property/ composition relationship, compounding, processing and commercial applications of: • Thermoplastic Polyolefinic Elastomers (TPOs). • Thermoplastic Polyurethane Elastomers (TPUs).	**10h**
Unit 4	Commercial Production/ Synthesis, structure, morphology, property/ composition relationship, compounding, processing and commercial applications of: **Elastomeric alloys-** • Thermoplastic Vulcanizates (TPVs). • Single Phase Melt Processible Rubber (MPRs).	**10h**

	Ionomers– Types and their application.	
Unit 5	Commercial Production/ Synthesis, structure, morphology, property/ composition relationship, compounding, processing and commercial applications of: Polyamide TPEs. **Applications of TPEs:** Automobile applications; Hose & tubing; Mechanical rubber goods; Elastic Applications; Medical applications & etc;	**10h**

Text book: Hand book of Thermoplastic Elastomers – Jiri George Drobny, William Andrew publications, Elsevier Inc, USA, 2014

References:

1. S. Fakirov (Edr), Handbook of Condensation Thermoplastic Elastomer, WILEY-VCH Verlag GmbH & Co.KGaA, Weinheim, 2005
2. John Scheirs and Duane B. Priddy (Edr), Modern Styrenic Polymers: Polystyrenes and Styrenic Copolymers, John Wiley & Sons Ltd., England, 2003
3. A. Dieter Schl¨uter, Craig J. Hawker, and Junji Sakamoto (Edr), Synthesis of Polymers Volume 1 Wiley-VCH Verlag & Co. KGaA, Germany, 2012
4. Benjamin. M.Walker & Charles .P.Rader, Hand book of Thermoplastic Elastomers –Vann Nostord Reinhold – compamy, New York, 1988
5. Gunter Oertel, Polyurethane Hand book, Hanser Publishers, New York, 1985
6. Raymond.W.Meyer, Hand book of Polyester molding compounds and Moulding Technology- Champaman & Hall, London, 1987.
7. Manrice Morton (Edr), Rubber Technology (3rd Edn.), Van Nostrand Reinhold Co. New York, 1987.
8. A. Brent Strong, Plastics materials & Processing, Prentice Hall, Ohio, 1996

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PT833: OPERATIONS RESEARCH (4-0-0)

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

CO1	Explain the art and science of operations research
CO2	Solve problems in linear programming to resolve real life industrial problems
CO3	Interpret and analyze advanced topics linear programming
CO4	Explain the concepts of project scheduling
CO5	Explain the concepts of queing theory

Course Content:

Unit1	Design Making in Operations Research: The art and science of operations research, A simple decision model, Art of modeling, Types of OR models, Effect of data availability on modeling, Computations in OR, Phases of OR study Linear Programming: Formulations and Graphical Solution, Simple LP model and its graphical solution, LP formulation , Additional LP formulation, The LP model and Resource Allocation	**10h**
Unit2	LP: Algebraic Solution, The standard from of the LP model, The Simplex method, Special cases in simplex method application, Interpreting the simplex tableau- Sensitivity Analysis LP: Transportation model, Definition and application of the transportation, Solution of the transportation problem, the assignment model, the transshipment model	**10h**
Unit3	LP: Advanced topics: Matrix definition of the standard LP problem, Foundations in LP, Revised simplex method, Bounded variables, Decomposition algorithm, Parametric LP	**10h**
Unit4	Project scheduling by PERT-CPM: Arrow(network) diagram representations, Critical path calculations, Construction of the time chart and resource leveling, Probability and cost considerations in project scheduling, Project control Inventory models: ABC inventory system, Generalized inventory model, Deterministic models, Probabilistic models	**10h**
Unit5	Queuing Theory (with mini applications): Basic elements of the queuing model, Roles of the Poisson and exponential distribution, Queues with combined arrivals and departures.	**10h**

Text book: Frederick K. Hiller, Bodhibrata Nag, Preetam Basu, Geralld J. Lieberman, Introduction to Operations Research, Jawahar Pub & Dist, 2011
References: 1. Ravindran , Phillips Solberg , Operations Research: Principles and Practice, 2012, UBS publishers. 2. Frederick K. Hiller. Introduction to Operations Research , 2012, UBS publishers

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PT84P: PROJECT WORK (0-0-10)

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

CO1:	Perform literature survey and select the relevant topic of research;
CO2:	Design project work based on research methodology foundation;
CO3:	Execute the project work in group and analyze the experimental data;
CO4:	Prepare the dissertation report;
CO5:	Present the subject understanding and research findings effectively.

Project work Guidelines:

Group formation: The project batches shall be formed after the sixth semester by the students and each group shall be balanced in terms of students having knowledge, skill and values; slow and fast learners; etc. The number of students in a batch shall normally be limited to four and in exceptional cases it may be five or less in some of the batches. (Under no circumstances, the number shall be more than five.)

Topic and Guide: Each group shall approach a staff member for his / her consent to supervise the project work. A faculty member shall guide at least one project batch and shall not guide more than two batches. Each group shall prepare a synopsis of the intended project work and submit the same to the department during seventh semester.

Project Work: the project work can be started in the seventh semester itself to have quality research. The work may be done in the campus or at any industry with prior permission or at both places as required. In case of industrial project, an external guide shall also be there. A student can take up any other project or internship at any time during his / her UG program for exposure but

should not disturb the final year project or other semester activities. Students can submit the proposals to funding agencies (like KSCST) in consent with guide, for sponsoring the project. The project work can be published in conference or journals in consent with the supervisor/s, which will fetch value to their career. Interdisciplinary topics, inter-departmental works are appreciated. The novel work can also be submitted for seeking the recognitions (like best student project award, etc). The work shall be systematically executed in par with 'Research Methodology'.

Project evaluation committee: The committee shall consist of guide (supervisor) and two faculty members identified by HOD for each group. The committee shall scrutinize the synopsis submitted by the project batches, shall give suggestions to improve the quality of work (if necessary) and approve the topic. Department shall announce the finalized list of groups, guide and topic in the first week of seventh semester. In case of any discrepancy, decision of HOD is final.

Evaluation: The project work shall have three CIE, been evaluated by the committee during the eighth semester to check the progress of the project work from time to time and suggest accordingly. Final evaluation (SEE) of the project work shall be done by the committee within ten days after the completion of SEE of theory subjects of eighth semester. The weight-age for the CIE and SEE shall be 70% and 30% respectively.

Report Submission: It is suggested that the project report, as a guideline, may be presented in the following form:

1. Cover page
2. Certificate/s
3. Abstract
4. Acknowledgement
5. Contents
6. List of Figures (If any)
7. List of Tables (If any)
8. Notations (Optional)
9. Introduction
10. Literature Review
11. Experimental Work

12. Results and Discussions

13. Conclusions

14. References.

The Project Report (two hard copies in the form of white soft bound and soft copy in PDF format in a CD) shall be submitted to the department in the standard format prescribed by the institution/ university (refer annexure-I for B.E. project), after the certification from concerned guide and HOD. (Individual student copies of report in soft bound/ hard bound form shall be submitted for attestation.)

Scheme of Project Work Evaluation:

Event	Period	Criteria Evaluated	Marks	COs	Total marks
CIE-I	Third week of January	Topic relevancy/ problem definition & discussion with mentor-	5	1	25
		Literature review-	10	1	
		Project Design: Method, Work Plan, Objective, Scope-	6	2	
		PPT slide preparation-	2	4	
		Presentation skill-	2	5	
CIE-II	Fourth week of February	Preliminary results- Presentation- Question & answer-	5 5 5	3 5 3	15
CIE-III	Fourth week of March	Final results- Discussion- Draft copy of report- Punctuality (involvement throughout project)- Ethics (plagiarism check, honesty, etc)-	10 5 5 5 5	3 5 4 3 2	30
SEE	Within 10 days after theory exams	Consolidated Presentation- Dissertation & CD- Viva-voce	10 10 10	5 4 5	30
Total Marks		CO1:15 + CO2:11 + CO3:25 + CO4:17 + CO5:32 =			**100**

Note: If score is <60% in any of the event then re-assessment is to be done.

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GE01PS: FUNCTIONAL POLYMERIC MATERIALS
(Add on course with GIAN course) (2-0-0)
Course Outcomes: Upon successful completion of this course, the students will be able to-

CO1:	Explain the basic principles and mechanisms of the stimuli-response for the most important smart materials.
CO2:	Explain the synthesis, properties and applications of smart polymeric materials
CO3:	Explain the applications of smart polymers

Course Content:

Unit 1	**Introduction:** Basic concepts of smart polymers, Types of smart polymer; Temperature-sensitive polymers, pH-sensitive polymers, Photo-sensitive polymers, magnetically responsive polymer, biointeractive polymers	**10h**
Unit 2	**Synthesis, properties and applications of** Hydrogels, Shape memory polymers, Self healing polymers and electro active polymers	**10h**
Unit 3	**Applications of smart polymers**: Biomedical application (drug delivery, therapy, minimal invasive surgery, tissue engineering, medical device), Optical data storage, Food industry, Packaging, Construction, Artificial muscle and Textiles	**10h**

Text Book

1. Smart Polymers and their Applications, Ed. Maria Rosa Aguilar, J.S. Román, Woodhead Publishing, 2014.

References:

1. Specialty Polymers: Materials and Applications, Ed. Faiz Mohammad, I. K. International Pvt Ltd, 2007
2. Handbook of Conducting Polymers, Second Edition, Ed. Terje A. Skotheim, CRC Press, 1997.
3. Smart Materials and Structures- M.V. Gandhi, B.S. Thompson, Chapman and Hall, London1992.
4. Electromechanical Sensors and Actuators, Ilene J. Busch-Vishniac, Springer-Verlag NY, 1999.
5. Fundamentals of Piezoelectricity- Takuro Ikeda, Oxford University Press, 1990.
6. Piezoelectric Senorics, G. Gautschi, Springer-Verlag Berlin Heidelberg, 2002.
7. Actauators: Basics and Applications H.armut Janocha (Ed), Springer-Verlag Berlin Heidelberg, 2004.

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