DEPARTMENT OF CHEMISTRY

ANNAUNIVERSITY, CHENNAI

VISION

The Department of Chemistry at Anna University shall strive towards attaining world class status and recognition by producing students with sound knowledge, professional skills, high levels of integrity and ethical values. The Department shall provide an outstanding ambience for teaching, research and consultancy. The Department shall perform frontier research and create knowledge base in theoretical and applied chemistry, polymeric and catalytic materials, fuel and energy related processes and materials, environmental chemistry and other trans disciplinary areas of technological importance.

MISSION

The Department of Chemistry, Anna University shall contribute to the educational, economic and social development by:

- Producing Postgraduates and Doctorates who are equipped with thorough knowledge in Chemistry, analytical thinking, practical skills and ethics by enabling interaction with experts from around the world in the fields of Chemistry.
- Inspiring the students to be creative thinkers, inspirational role models and citizens with environmental and social consciousness.
- Ensuring a supportive ambience in the Department with dynamic leadership and growth opportunities to meet the needs of the students, faculty and staff.
- Promoting the development of technologically and socially relevant processes and products in the fields of catalysis, polymers, corrosion resistance coatings and energy conversion through academic and sponsored research, in collaboration with global research groups.
- Facilitating collaborative partnership with industries and other institutions and catalyze innovation, transfer of technology and commercialization towards fulfilling societal developments.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

Master of Polymer Science and Engineering curriculum is designed to prepare the graduates to

I.	Provide an interdisciplinary specialization in master's degree with an emphasis on polymeric materials and their processing.
II.	Undertake a career in industries that involve innovation, problem–solving and Leadership in polymer science.
III.	Excel both in academia and R&D organizations involving polymeric materials.
IV.	Contribute to the society by becoming a model citizen with high standards of intellectual qualities having good academic skills and personal honesty.
V.	Enable the graduates to engage in life-long learning with social and ethical responsibility.

I. PROGRAMME OUTCOMES (POs)

PO	Programme Outcomes After successful completion of the programme, the students will be able to
1	Independently carry out research/investigation and development work to solve practical problems.
2	Write and present a substantial technical report/document.
3	Demonstrate a degree of mastery over the area as per the specialization of the program. The mastery shall be at a level higher than the requirements in the appropriate bachelor program.
4	Develop an in-depth expertise in the field of polymers that encourage them for higher studies and continuous professional development.
5	Construct successful career in industries of international repute and help them to excel in this field.
6	Create an operational expertise for successful entrepreneurship.

PEO/PO Mapping:

PEO	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
I.	3	2	3	3	2	2
II.	3	2	3	3	3	3
III.	3	3	3	3	3	3
IV.	3	2	3	3	3	2
V.	3	3	3	3	3	3

PROGRAMME ARTICULATION MATRIX

Year	Semester	Course name	PO					
			1	2	3	4	5	6
I	I	Polymer Chemistry	2	1	2	1	1	1
		Science of Polymeric Materials	1	2	3	1	2	1
		Polymer Process Engineering	2	1	2	2	2	2
		Professional Elective I						
PRACTICALS								
		Polymer Science Lab	3	2	3	2	3	2
		Polymer Processing and Testing Lab	2	2	3	2	2	1

Year	Semester	Course name	PO					
			1	2	3	4	5	6
I	II	Characterization and Testing of Polymers	3	2	3	2	2	2
		Unit Operations	2	2	2	2	1	2
		Process Control in Polymer Industry	1	1	2	1	2	1
		Polymer Product and Mold Design	1	1	1	1	2	2
		Professional Elective II						
		Professional Elective III						
PRACTICALS								
		Polymer Analysis & Characterization Lab	2	1	2	2	1	1
		Mould Design and Analysis Laboratory	1	1	1	1	2	2
		Seminar	2	2	2	1	1	2

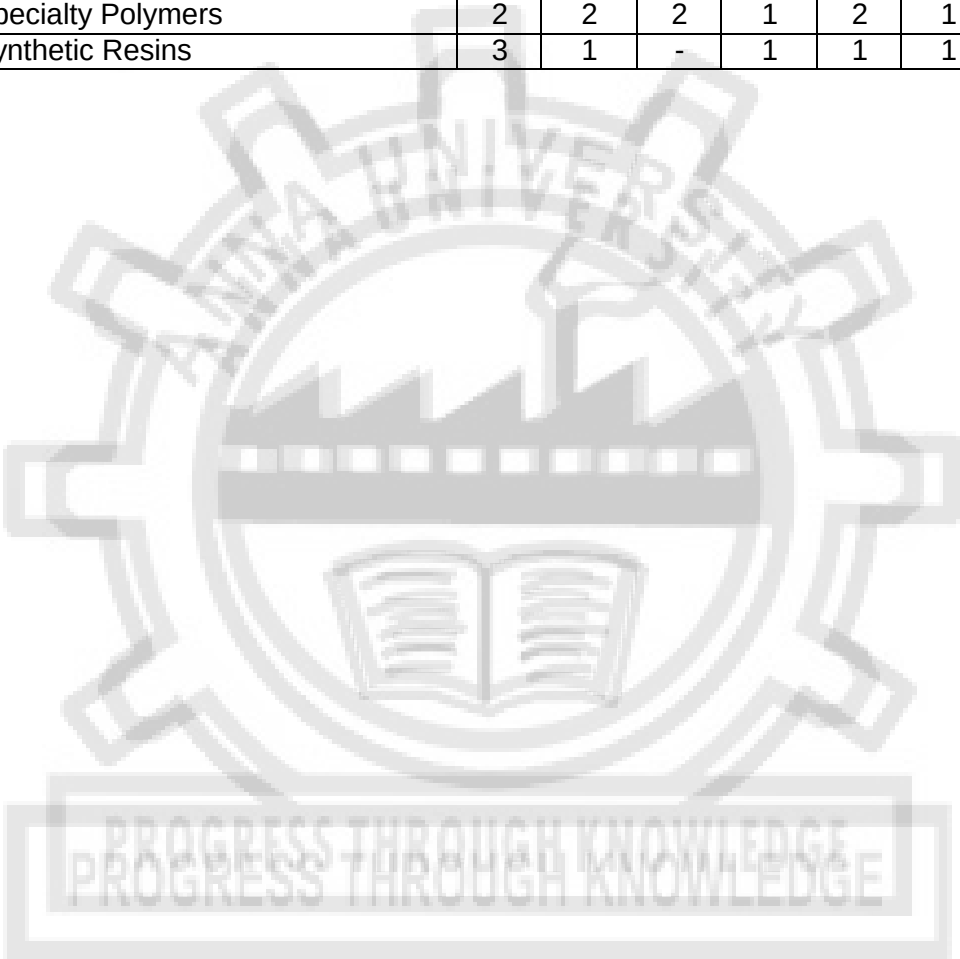
Year	Semester	Course name	PO					
			1	2	3	4	5	6
PRACTICALS								
II	III	Professional Elective IV						
		Professional Elective V						
		Professional Elective VI						
		Internship/Training(Minimum 4Weeks)	3	3	2	3	3	3
		Project Work I	3	3	3	3	3	3

Year	Semester	Course name	PO					
			1	2	3	4	5	6
PRACTICALS								
II	IV	Project Work II	3	3	3	3	3	3

MAPPING OF ELECTIVES AND PROGRAMME OUTCOMES

Sl.No.	Course name	PO					
		1	2	3	4	5	6
1	Additives and Compounding of Plastics	3	1	3	2	2	-
2	Additive Manufacturing	3	1	2	2	3	2
3	Adhesive and Coating Technology	3	1	3	1	3	3
4	Biopolymers and Biodegradable Polymers	2	1	3	1	-	-
5	CAD/CAM Application in Mould/Tool Design	3	1	3	2	3	-
6	Composites Technology	3	2	2	2	3	2

7	Conducting Polymers	3	2	2	2	2	2
8	High Performance Polymers	3	2	2	3	2	1
9	Plastics Mould Manufacturing Technology	1	3	3	2	-	3
10	Polymer Blends	3	2	3	1	1	1
11	Polymer Nanocomposites	3	2	1	2	3	2
12	Polymer Reaction Engineering	2	2	2	2	2	2
13	Plastic Waste Management	2	1	1	1	2	3
14	Polymers for Biomedical Engineering Applications	2	1	2	3	1	3
15	Polymers for Packaging Applications	2	1	3	1	1	2
16	Rubber Technology	3	2	3	2	2	3
17	Specialty Polymers	2	2	2	1	2	1
18	Synthetic Resins	3	1	-	1	1	1



ANNA UNIVERSITY, CHENNAI UNIVERSITY DEPARTMENTS
M.TECH. POLYMER SCIENCE AND ENGINEERING
REGULATIONS – 2023
CHOICE BASED CREDIT SYSTEM
CURRICULUM AND SYLLABI FOR I TO IV SEMESTER
SEMESTER I

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	MA3161	Statistical Methods for Engineers	FC	4	0	0	4	4
2.	RM3151	Research Methodology and IPR	RMC	2	1	0	3	3
3.	PL3101	Polymer Chemistry	PCC	3	0	0	3	3
4.	PL3102	Science of Polymeric Materials	PCC	3	0	0	3	3
5.	PL3103	Polymer Process Engineering	PCC	3	0	0	3	3
6.		Professional Elective I	PEC	3	0	0	3	3
PRACTICALS								
7.	PL3111	Polymer Science Lab	PCC	0	0	4	4	2
8.	PL3112	Polymer Processing and Testing Lab	PCC	0	0	4	4	2
			TOTAL	**18**	**1**	**8**	**27**	**23**

SEMESTER II

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.	PL3201	Characterization and Testing of Polymers	PCC	3	0	0	3	3
2.	PL3202	Unit Operations	PCC	3	0	0	3	3
3.	PL3203	Process Control in Polymer Industry	PCC	3	0	0	3	3
4.	PL3204	Polymer Product and Mould Design	PCC	3	0	0	3	3
5.		Professional Elective II	PEC	3	0	0	3	3
6.		Professional Elective III	PEC	3	0	0	3	3
PRACTICALS								
7.	PL3211	Polymer Analysis and Characterization Lab	PCC	0	0	4	4	2
8.	PL3212	Mould Design and Analysis Laboratory	PCC	0	0	4	4	2
9.	PL3213	Seminar	EEC	0	0	2	2	1
			TOTAL	**18**	**0**	**10**	**28**	**23**

SEMESTER III

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
THEORY								
1.		Professional Elective IV	PEC	3	0	0	3	3
2.		Professional Elective V	PEC	3	0	0	3	3
3.		Professional Elective VI	PEC	3	0	0	3	3
PRACTICALS								
4.	PL3311	Internship/Training (Minimum4Weeks)	EEC	0	0	4	4	2
5.	PL3312	Project Work I	EEC	0	0	12	12	6
			TOTAL	**9**	**0**	**16**	**25**	**17**

SEMESTER IV

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS	CREDITS
				L	T	P		
PRACTICALS								
1.	PL3411	Project Work II	EEC	0	0	24	24	12
			TOTAL	**0**	**0**	**24**	**24**	**12**

TOTAL NO. OF CREDITS: 75

LIST OF PROFESSIONAL CORE COURSES (PCC)

S. No.	COURSE CODE	COURSETITLE	L	T	P	C	SEMESTER
1	PL3101	Polymer Chemistry	3	0	0	3	I
2	PL3102	Science of Polymeric Materials	3	0	0	3	I
3	PL3102	Polymer Process Engineering	3	0	0	3	I
4	PL3201	Characterization and Testing of Polymers	3	0	0	3	II
5	PL3202	Unit Operations	3	0	0	3	II
6	PL3203	Process Control in Polymer Industry	3	0	0	3	II
7	PL3204	Polymer Product and Mould Design	3	0	0	3	II
8	PL3111	Polymer Science Lab	0	0	4	2	I
9	PL3112	Polymer Processing and Testing Lab	0	0	4	2	I
10	PL3211	Polymer Analysis and Characterization Lab	0	0	4	2	II
11	PL3212	Mould Design and Analysis Lab	0	0	4	2	II

PROFESSIONAL ELECTIVE COURSES

S. No.	COURSE CODE	COURSETITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PL3001	Additives and Compounding of Plastics	PEC	3	3	0	0	3
2.	PL3002	Additive Manufacturing	PEC	3	3	0	0	3
3.	PL3003	Adhesive and Coating Technology	PEC	3	3	0	0	3
4.	PL3004	Biopolymers and Biodegradable Polymers	PEC	3	3	0	0	3
5.	PL3005	CAD/CAM Application in Mould/Tool Design	PEC	3	3	0	0	3
6.	PL3006	Composites Technology	PEC	3	3	0	0	3
7.	PL3007	Conducting Polymers	PEC	3	3	0	0	3
8.	PL3008	High Performance Polymers	PEC	3	3	0	0	3
9.	PL3009	Plastics Mould Manufacturing Technology	PEC	3	3	0	0	3
10.	PL3010	Polymer Blends	PEC	3	3	0	0	3
11.	PL3011	Polymer Nanocomposites	PEC	3	3	0	0	3
12.	PL3012	Polymer Reaction Engineering	PEC	3	3	0	0	3
13.	PL3013	Plastic Waste Management	PEC	3	3	0	0	3
14.	PL3014	Polymers for Biomedical Engineering Applications	PEC	3	3	0	0	3
15.	PL3015	Polymers for Packaging Applications	PEC	3	3	0	0	3
16.	PL3016	Rubber Technology	PEC	3	3	0	0	3
17.	PL3017	Specialty Polymers	PEC	3	3	0	0	3
18.	PL3018	Synthetic Resins	PEC	3	3	0	0	3

LIST OF EMPLOYABILITY ENHANCEMENT COURSES (EEC)

S. No.	COURSE CODE	COURSETITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	PL3213	Seminar	EEC	2	0	0	2	1
2.	PL3311	Internship / Industrial Training	EEC	4	0	0	4	2
3.	PL3312	Project Work I	EEC	12	0	0	12	6
4.	PL3411	Project Work II	EEC	24	0	0	24	12
							TOTAL CREDITS	**21**

SUMMARY

Sl. No.	Name of the Programme : M.Tech (Polymer Science and Engineering)					
	SUBJECT AREA	CREDITS PER SEMESTER				CREDITS TOTAL
		I	II	III	IV	
1.	FC	4	-	-	-	4
2.	PCC	13	16	-	-	29
3.	PEC	3	6	9	-	18
4.	RMC	3	-	-	-	3
5.	EEC	-	1	8	12	21
6.	**TOTAL CREDITS**	**23**	**23**	**17**	**12**	**75**

MA3161 STATISTICAL METHODS FOR ENGINEERS L T P C
4 0 0 4

OBJECTIVES:

To prepare the students to

- Execute estimation of the parameters involved in the specific distribution from a possible continuum of alternatives.
- Value the testing of statistical hypothesis claimed based on a set of data points using suitable test statistics which follows standard sampling distributions.
- Formulate a relationship that make it possible to predict one or more variable in terms of others using correlation and regression analysis.
- Develop various experimental designs and their corresponding analysis of variance which play vital role in many real time scenarios.
- Support handling random vectors which represent random variables in multi-dimensional space.

UNIT I ESTIMATION THEORY 12

Estimators: Unbiasedness, Consistency, Efficiency and Sufficiency–Maximum Likelihood Estimation – Method of moments.

UNIT II TESTING OF HYPOTHESIS 12

Tests based on Normal, *t*, χ^2 and *F* distributions for testing of means, variance and proportions – Analysis of *r x c* tables – Goodness of fit.

UNIT III CORRELATION AND REGRESSION 12

Multiple and Partial Correlation - Method of Least Squares- Plane of Regression - Properties of Residuals - Coefficient of Multiple Correlation - Coefficient of Partial Correlation - Multiple Correlation with total and partial correlations - Regression and Partial correlations in terms of lower order coefficients.

UNIT IV DESIGN OF EXPERIMENTS 12

Analysis of variance – One - way and two - way classifications – Completely randomized design – Randomized block design – Latin square design.

UNIT V MULTIVARIATE ANALYSIS 12

Random vectors and Matrices – Mean vectors and Covariance matrices – Multivariate Normal density and its properties – Principal components: Population principal components – Principal components from standardized variables.

TOTAL: 60 PERIODS

OUTCOMES:

At the end of the course, students will be able to

CO1 Estimate the value of the point estimators using the method of moments and method of maximum Likelihood.

CO2 Value various test statistics in hypothesis testing for mean and variances of large and small samples.

CO3 Formulate the regression line using the method of least square and also to calculate the partial and multiple correlation coefficients for the given set of data points.

CO4 Develop the hypothesis for several means using one way, two way or three way classifications.

CO5 Support the principal component analysis of random vectors and matrices.

REFERENCES:

1. Devore, J.L., “Probability and Statistics for Engineering and the Sciences”, Thomson and Duxbury, Singapore, 6th Edition, Boston, 2004.
2. Gupta, S.C., and Kapoor, V.K., “Fundamentals of Mathematical Statistics”, Sultan Chand and Sons, Eleventh Edition, Reprint, New Delhi, 2019.
3. Johnson, R. A. and Gupta, C. B., “Miller & Freund’s Probability and Statistics for Engineers”,

Pearson Education, Asia, Eighth Edition, New Delhi, 2015.
4. Johnson, R.A., and Wichern, D.W., “Applied Multivariate Statistical Analysis”, Pearson Education, Sixth Edition, New Delhi, 2013.
5. Spiegel, M.R. and Stephens, L.J.,” Schaum’s outlines on Statistics”, Tata McGraw-Hill, 6th Edition, New York, 2018.

CO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	2
CO2	3	3	3	3	2	2
CO3	3	3	3	3	2	2
CO4	3	3	3	3	2	2
CO5	3	3	3	3	2	2
Ava	3	3	3	3	2	2

RM3151 RESEARCH METHODOLOGY AND IPR L T P C
2 1 0 3

UNIT I RESEARCH PROBLEM FORMULATION 9

Objectives of research, types of research, research process, approaches to research; conducting literature review- information sources, information retrieval, tools for identifying literature, Indexing and abstracting services, Citation indexes, summarizing the review, critical review, identifying research gap, conceptualizing and hypothesizing the research gap

UNIT II RESEARCH DESIGN AND DATA COLLECTION 9

Statistical design of experiments- types and principles; data types & classification; data collection - methods and tools

UNIT III DATA ANALYSIS, INTERPRETATION AND REPORTING 9

Sampling, sampling error, measures of central tendency and variation,; test of hypothesis- concepts; data presentation- types of tables and illustrations; guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript; guidelines for wring thesis, research proposal; References – Styles and methods, Citation and listing system of documents; plagiarism, ethical considerations in research

UNIT IV INTELLECTUAL PROPERTY RIGHTS 9

Concept of IPR, types of IPR – Patent, Designs, Trademarks and Trade secrets, Geographical indications, Copy rights, applicability of these IPR; , IPR & biodiversity; IPR development process, role of WIPO and WTO in IPR establishments, common rules of IPR practices, types and features of IPR agreement, functions of UNESCO in IPR maintenance.

UNIT V PATENTS 9

Patents – objectives and benefits of patent, concept, features of patent, inventive steps, specifications, types of patent application; patenting process - patent filling, examination of patent, grant of patent, revocation; equitable assignments; Licenses, licensing of patents; patent agents, registration of patent agents.

TOTAL: 45 PERIODS

REFERENCES:

1. Cooper Donald R, Schindler Pamela S and Sharma JK, “Business Research Methods”, Tata McGraw Hill Education, 11e (2012).
2. Soumitro Banerjee, “Research methodology for natural sciences”, IISc Press, Kolkata, 2022,
3. Catherine J. Holland, “Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets”, Entrepreneur Press, 2007.
4. David Hunt, Long Nguyen, Matthew Rodgers, “Patent searching: tools & techniques”, Wiley, 2007.
5. The Institute of Company Secretaries of India, Statutory body under an Act of parliament,

"Professional Programme Intellectual Property Rights, Law and practice", September 2013.

PL3101 POLYMER CHEMISTRY L T P C
3 0 0 3

OBJECTIVE

To prepare the students to

- Identify the polymers, classification and mechanism of polymerization.
- Relate the kinetics of copolymerization, reactivity ratios and composition of copolymer.
- Differentiate molecular weight, solubility and fractionation of polymers.
- Distinguish polymers by thermal and mechanical properties.

UNIT I POLYMERS AND CHAIN GROWTH POLYMERIZATION 9

Basics – polymer classifications based on occurrence, types, process, and end uses. Kinetics and mechanism of free radical, cationic, anionic, living polymers and coordination polymerization– Ziegler Natta catalysts- monometallic mechanism–stereo regular polymerization–chain transfer reaction and constant.

UNIT II STEP GROWTH POLYMERIZATION AND COPOLYMERIZATION 9

Kinetics of condensation polymerization–copolymerization-kinetics–copolymer equation composition of copolymers by NMR–monomer -reactivity ratios and their significance– polymerization reactions - metathetical, electrochemical, Group transfer polymerization and ring opening.

UNIT III STRUCTURAL PROPERTIES AND REACTION OF POLYMER MOLECULES 9

Functionality – tacticity of polymer – chemical and geometrical structure – ladder, star and telechelic polymers – interpenetrating networks - Polymers - crystalline amorphous nature– crystallizability - effect on properties. Reactions of polymer molecules with specific groups OH, CHO, C=O, COOH and – NH_2 and polymer – cross linking, cyclisation–polymer degradation-thermal, mechanical, photo and radiation.

UNIT IV THERMAL TRANSITION, MOLECULAR WEIGHT AND POLYMER DISSOLUTION 9

Thermal transitions–TGA, DSC, HDT, MFI -.Number, weight and viscosity average molecular weights – polydispersity - molecular weight distribution – determination of molecular weight by GPC and viscometry – polymer dissolution - thermodynamics of polymer dissolution – solubility parameter–fractionation of polymers.

UNIT V BIOAND INORGANIC POLYMERS 9

Naturally occurring polymers – starch, proteins, cellulose – Derivatives of cellulose polymers – rayon, cellophane, cellulose acetate, butyrate and nitrate – ethyl cellulose – carboxy methylcellulose - preparation, properties - application of organo metallic polymers –co-ordination polymers – polyamides- Inorganic polymers - phosphorous and nitrogen containing polymers – silicones – hybrid polymers – iniferters.

TOTAL:45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO 1: Design the polymers with required molecular weight and properties.

CO 2: Relate kinetics of copolymerization, reactivity ratio and copolymer composition.

CO 3: Analyze structure-property relationship in polymers

CO 4: Design polymers with required thermal transitions and select appropriate method to determine molecular weight of polymers

CO 5: Compare and discuss about the properties of bio-polymers and inorganic polymers.

REFERENCEBOOKS:

1. R.J. Young, Introduction to Polymers, Chapman and Hall Ltd., London, 1999.

2. Gorge Odeon – Principles of Polymerization, 4th edition, McGraw Hill Book Company, New
3. V.R. Gowarikar, Polymer Science, New Age International Pvt Ltd Publishers, 2010.
4. Manas Chanda, SalilK.Roy," Plastics Technology Hand book ", 2nd edition, Marcel Dekker, New York,1993.
5. H.F.Mark,(Ed)," Encyclopedia of polymer Science & Engineering". John Wiley & Sons, New York, 1989.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	2	2	1
CO2	2	1	2	1	1	1
CO3	2	1	2	1	1	1
CO4	2	1	2	1	1	1
CO5	2	1	2	1	2	1
Average PO	**2**	**1.2**	**2.2**	**1.2**	**1.4**	**1**

PL3102 SCIENCE OF POLYMERIC MATERIALS L T P C
3 0 0 3

OBJECTIVE

To prepare the students to

- Judge the polymer structure from configuration and conformation of the polymer microstructure.
- Evaluate thermal and mechanical properties of the polymers.
- Value the electrical properties of the polymers with various additives.
- Analyze the rheological properties of the polymers.

UNIT I INTRODUCTION 9

Polymer structure – chain structure – micro structure – crystal structure - crystallinity – determination of crystallinity, size and orientation of crystallites using x-rays-conformation and configuration.

UNIT II MECHANICAL PROPERTIES 9

Deformation of plastic materials- classification of plastic materials based on their stress –strain relationship – effect of temperature on deformation - time dependence and visco elasticity in solid plastics – Boltzmann's superposition principle- dynamic mechanical properties– yielding of plastics – mechanical failure in plastics.

UNIT III THERMAL PROPERTIES 9

Enthalpy – melting and crystallization – importance of Tg – factors affecting Tg – determination of Tg – thermal conductivity – thermal expansion and contraction – factors affecting thermal expansion.

UNIT IV ELECTRICAL PROPERTIES 9

Effect of polymer structure on dielectric constant, power factor, dissipation factor, and loss factor – effect of frequency of voltage and temperature on dielectric properties – Effect of additives on electrical properties of polymers. Electrical properties at low stress and high stress - breakdown mechanisms – electrically conductive plastics – electrical applications of plastics. ITA, the school of engineers in computer

UNIT V RHEOLOGICAL PROPERTIES 9

Melt flow properties - fundamental concepts of rheology – geometry of flow – rheological and viscous behavior in simple shear - viscous properties of plastic melts in simple shear-

measurement of shear properties; viscometry – types of capillary viscometer- factors affecting shear flow and elongational flow – MFI, melt elasticity

TOTAL: 45 PERIODS

COURCE OUTCOMES:

At the end of the course, students will be able to

CO 1 : Judge the crystallinity and evaluate morphology of polymers
CO 2 : Select plastic materials based on their mechanical properties for specific applications.
CO 3 : Develop and assess thermal properties of polymers.
CO 4 : Relate electrical properties and applications of plastics.
CO 5 : Evaluate the rheological properties of plastics

REFERENCE BOOKS:

1. Birley, Haworth, Batchelor, Physics of Plastics – Processing
2. Properties and Materials Engineering, Hamer Publication, 1992.
3. N.C. McCrum et.al, Principles of Polymer Engineering, 2nd edition Oxford University Press, London, 1997.
4. Bever, Encyclopedia of Materials Science and Engg., Volume 7, Pergamon press, London, 1986.
5. L. H. Sperling, "Introduction to physical polymer science, 4th edn, Wiley, 2005.
6. Zehev Tadmor, Costas G. Gogos, Principles of Polymer Processing, 2nd Edition, Wiley, 2006.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	--	--	3	--	--	--
CO2	--	2	--	1	2	1
CO3	1	--	--	1	--	--
CO4	--	--	3	--	2	--
CO5	--	2	--	--	--	--
Average PO	**1**	**2**	**3**	**1**	**2**	**1**

PL3103 POLYMER PROCESS ENGINEERING L T P C
3 0 0 3

OBJECTIVES

To prepare the students to

- Value the aspects of processing of polymers.
- Criticize the advancements in Injection and Blow moulding.
- Validate the importance of injection moulding.
- Review the special moulding techniques.
- Execute the die forming and mould making.

UNIT I PROCESSING OF POLYMERS 9

Introduction to polymer processing, quantitative aspects of polymer product processing additives and compounding – fillers, plasticizers, antioxidants, colorants, flame retardants, stabilizers compounding, mixing and compounding equipment.

UNIT II EXTRUSION AND BLOW MOULDING 10

Analysis of flow in extruder - drag flow, pressure flow, leak flow - extruder/die characteristics - screw geometry -basic flow patterns in extrusion die - die exit instabilities - die swell -processing methods based on extruder (granule production, profile production, pipe and corrugated pipe, co extrusion, film blowing, multilayer extrusion) - blow moulding - extrusion and injection stretch blow moulding, advance blow moulding - deep draw double wall blow moulding, press blow moulding, 3 dimensional blow moulding - extrusion coating process (sheet coating and wire covering).

UNIT III INJECTION MOULDING 9

Injection moulding machines and its components, its types- its process - moulds, multi cavity moulds, mould clamping devices, mould clamping force, disc moulding, injection blow moulding, reaction injection moulding - co injection moulding - two colour injection moulding - gas assisted injection moulding - multi layer injection moulding - liquid injection moulding - counter flow moulding.

UNIT IV SPECIAL MOULDING TECHNIQUES 10

Analysis of calendaring, methods of sheet forming - Thermoforming - vacuum forming, pressure forming and matched mould forming - Rotation moulding, processing and analysis of compression moulding, transfer moulding -sintering - solution casting - Sheet molding and dough molding compounds - Processing technology of elastomers - processing of natural and synthetic rubbers - vulcanization, mastication and cyclisation -plastic finishing techniques, powder coating, metallizing.

UNIT V TOOLING AND MOULDS 7

Tool making processes, die and die forming, compression moulds, transfer moulds, blow and extrusion dies, typical exercises in mould design and production, two plate mould, three plate mould, hot runner mould, insulated runner mould, runners, gates, mould making, mould cooling.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Value the processing of polymers

CO2:Criticize extrusion and blow moulding and select a preferred plastic production process based on requirement.

CO3: Analyze the merits and demerits in various types of injection moulding

CO4: Validate the advancement in the special moulding techniques and develop skill to critically evaluate design of plastic product based on it.

CO5: Solve the mathematical calculations involved in the planning and design of moulds and dies.

REFERENCE BOOKS:

1. John Brydson, “Plastic materials”, 7th edition, Butterworth – Heinamann Ltd., London, 2014.
2. J.A. Biesenberger and H.Sebastian, “Principles of Polymerization Engineering”, WileyInterscience Publication, New York, 2004.
3. Charles A.Harper, “Hand book of Plastic Processing”, Willey Publication,2014
4. W.S. Allen & P.N. Baker, “Hand Book of Plastic Technology”, Vol.1, CBS publishers,2009.
5. Myer Kutz, “Applied Plastics Engineering Handbook: Processing, Materials and Applications”, 2 nd edition, 2017.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	1	2	2	2
CO2	2	1	2	2	2	2
CO3	2	1	2	2	2	2
CO4	2	1	2	2	2	2
CO5	2	1	1	2	2	1
Average PO	**2**	**1**	**1.6**	**2**	**2**	**1.8**

PL3111 POLYMER SCIENCE LAB L T P C

0 0 4 2

OBJECTIVES

To prepare the students to

- Experiment polymer synthesis and kinetics of polymerization

- Experience on reactivity ratio and molecular weight of polymers
- Interpret the importance of fractionation of polymers.
- Prepare high molecular weight polymer using emulsion polymerization technique.

UNIT I POLYMERIZATION TECHNIQUES 20

Polymer synthesis - bulk, solution, emulsion, suspension and slurry polymerization- low and high temperature condensation polymerization, interfacial poly-condensation, thermal and redox initiated polymerizations - kinetics of polymerization - preparation of IPN polymer.

UNIT II PREPARATION OFCOPOLYMERANDTHERMOSETRESIN 20

Copolymerization of styrene and MMA - determination of reactivity ratio of MMA - styrene copolymer, preparation of an epoxy resin and unsaturated polyester resin, PF, UF, MF resin - determination of cure of resin - determination of acid value of resin.

UNIT III MOLECULAR WEIGHTDETERMINATION 10

Determination of Molecular weight - viscometry, end group analysis, GPC, light scattering, osmometry.

UNIT IV FRACTIONATIONOFPOLYMERS 5

Fractionation of polymers – Fractional precipitation method - poly - dispersity.

UNIT V EMULSION-PAINT 5

Emulsion polymerization - paint formulation, coating.

TOTAL :60 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Synthesize polymers and discuss about the kinetics of polymerization.
CO2: Prepare copolymers and thermosets.
CO3: Calculate molecular weight of polymers by different methods.
CO4: Construct methods for fractionation of polymers
CO5: Experience the preparation of paint by emulsion polymerization technique.

REFERENCE BOOKS:

1. Edward A. Colloind, J.Bares and F.W. Billmeyer Jr., “Experiments in Polymer Science”, Wiley Interscience, New York 1973.
2. Wayne R.Sorenson and T.W.Campbell, “Preparative Methods of Polymer Chemistry” 3rd edition, Wiley – Interscience, New York, 2001.
3. Tim A. Oswald Georg Menges, “Material Science of Polymers for Engineers”, Hanser Publications, 2012.
4. E.M.McCaffery, “Laboratory Preparation for Macromolecular Chemistry”, McGraw Hill, Kogakush, 1970.
5. Chorng- Shyan Chern, “Principle and Application of Emulsion Polymerization”, John Wiley& Sons, 2008.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	3	3
CO2	3	2	3	2	2	3
CO3	3	2	3	2	3	1
CO4	2	2	3	2	2	2
CO5	2	2	3	2	3	2
Average PO	2.6	2	3	2	2.6	2.2

PL3112 POLYMER PROCESSING AND TESTING LAB L T P C
0 0 4 2

OBJECTIVES:

To prepare the students to

- Experiment testing of polymers using various standards.
- Select suitable molding techniques.

- Construct sample preparation techniques.
- Relate parts and functions of various processing equipments.
- Experience compounding and mixing operations.

UNIT I MECHANICAL TESTING 15

UTM- tensile, compression, flexural - Impact test- Izod/Charpy - Abrasion resistance and Rockwell hardness test, Durometer.

UNIT II THERMAL, ELECTRICAL AND OPTICAL TESTING 10

Heat deflection temperature, Vicat softening point, Adhesion testing, Dielectric test and arc resistance - Light transmittance and Opacity - gloss.

UNIT III PRODUCT TESTING 10

Bottle testing - drop impact, Pipe testing - hydrostatic pressure (Burst strength) -Woven sack and film testing - UTM, dart impact.

UNIT IV PROCESSING 15

Injection molding**-** Compression molding**-** Extrusion- pipe, films, rods -Blow molding - FRP – Hand layup process, Thermoforming.

UNIT V MIXING/BLENDING 10

Two roll mill- Banbury mixer- ribbon blender.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Select methods to analyze mechanical properties of plastics.
CO2: Experiment thermal and electrical properties of plastics.
CO3: Analyze the test results obtained from polymer product testing.
CO4: Evaluate the suitable processing method for polymers as per product requirement.
CO5: Design and formulate polymer compounds.

REFERENCE BOOKS:

1. R.P. Brown, “Hand Book of Plastics Test Methods”, George Godwin Ltd., London,1981
2. Vishu Shah, “Hand Book of Plastics Testing Technology”, John Wiley & Sons. Inc.New York, 1998.
3. Brycle, D.M., “Plastics Injection Moulding”
4. Schwartz & Goodman., “Plastics Materials & Processing”
5. Levy, Sydney and Carley, James F., “Plastics Extrusion Technology Hand Book”, 2nd edition, Industrial Press Inc., Newyork 1989.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	2	2	1
CO2	2	2	3	2	2	1
CO3	2	2	3	2	2	1
CO4	2	2	3	2	2	1
CO5	2	2	3	2	2	1
Average PO	2	2	3	2	2	1

PL3201 CHARACTERIZATION AND TESTING OF POLYMERS L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Compare various spectroscopic characterizations of polymers.
- Evaluate the thermal and electrical properties of polymers

- Value mechanical properties and hardness of plastics
- Distinguish flammability, ignition and optical properties.
- Support the properties of polymers with different testing of plastics.

UNIT I SPECTROSCOPIC CHARACTERIZATION 9

Vibrational spectroscopy (FTIR, ATRIR and Raman spectroscopy), UV-visible and photoluminescence, XPS, NMR, mass spectroscopy, Thermal analysis (TGA, DTA, DSC, DMA, TMA) - Electron Microscopes (SEM, TEM, AFM) - Chromatography (GC, GPC) - X-ray Diffraction - Structure Identification (IR, NMR) - Melt index and viscosity.

UNIT II THERMAL AND ELECTRICAL PROPERTIES 9

Thermal conductivity - Thermal Expansion - Linear coefficient - HDT - VICAT softening - Brittleness - Temperature - dielectric strength, dielectric constant, dissipation factor - arc resistance.

UNIT III MECHANICAL PROPERTIES AND HARDNESS 9

Tensile tests - strength, modulus and Elongation - Flexural and compression properties - Impact properties - Types - Izod - charpy, chip and drop impact tests – Abrasion Resistance (Transparent / Flat specimen) -Hardness tests (Rockwell, Durometer, Barcol).

UNIT IV FLAMMABILITY, IGNITION & OPTICAL PROPERTIES AND ANALYTICAL TESTS 9

Flammability test (Non rigid, solid plastics) Ignition Temperature-Oxygen Index Test - Refractive Index, luminous transmittance, haze, Specular gloss, clarity, Photoelasticity, Birefringence ,density, water absorption, moisture analysis - sieve analysis, crush and burst strength.

UNIT V TESTING OF FOAM PLASTICS, NON DESTRUCTIVE TESTING AND TESTING ORGANIZATIONS 9

Foam properties, rigid, flexible foam - methods of testing - ultrasonic measurement techniques techniques – pulse eco -transmission-resonance – application - ASTM, ANSI, NBS, NEMA, NFPA, VL, SPI AND SPE-Organizations.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Compare various spectroscopic characterization techniques of polymers.
CO2: Evaluate thermal and electrical properties of polymers
CO3: Analyze the test results of mechanical properties of polymers.
CO4: Distinguish ignition, optical and analytical tests of polymer and interpret the test results.
CO5: Support and judge NDT testing of plastics and explain the relevance of standards and specifications.

REFERENCE BOOKS:

1. A. B. Mathur, I. S. Bharadwaj, Testing and Evaluation of Plastics, Allied Publishers Pvt. Ltd., New Delhi, 2003
2. A. Ya. Malkin, A.A. AskaDsky, V.V. Koverica Experimental methods of polymers, Mir Publishers, Moscow, 1998.
3. Iver, Mead and Riley, Hand book of Plastic test methods, Illith Publishers, New York, 1982.
4. S. K. Nayak, S. N. Yadav, S. Mohanty, Fundamentals of Plastic Testing, Springer, 2010.
5. Vishu Shah, Hand book of Plastics Testing and Failure Analysis, 3rd Edition, John- Willey &Sons, New York, 2007.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	2	2
CO2	3	2	3	2	2	1
CO3	3	2	3	2	2	2
CO4	3	2	3	2	2	2
CO5	3	2	3	2	2	2
Average PO	**3**	**2**	**3**	**2**	**2**	**1.8**

PL3202 **UNIT OPERATIONS** **L T P C**
3 0 0 3

OBJECTIVES:

To prepare the students to

- Select unit operations and appreciate their importance in polymer industries.
- Value the concepts of heat transfer by conduction and convection process.
- Judge the analogy between heat and momentum transport processes.
- Design equations for convective mass transfer.

UNIT I MOMENTUM TRANSPORT PROCESS **9**

Momentum transport – fluid behavior – overall mass, energy and momentum balances – differential mass, energy and momentum balance - polymeric liquids.

UNIT II SOLUTION TO EQUATIONS OF MOTION **9**

Solution to equations of motion - boundary layer flow – turbulent flow– dimensional analysis applied to momentum transport – design equation for incompressible fluid flow through packed column – fluidization.

UNIT III HEAT TRANSFER BY CONDUCTION PROCESS **9**

Heat transfer – steady state conduction – unsteady state conduction – numerical and graphical methods in analysis of heat conduction.

UNIT IV CONVECTIVE HEAT TRANSFER PROCESS **9**

Convective heat transfer – heat transfer in laminar and turbulent flow- boiling and condensation – design equations for convective heat transfer – heat exchangers.

UNIT V MASS TRANSFER **9**

Mass transfer – molecular diffusion – binary systems – convective mass transfer coefficients – mass transfer in laminar and turbulent flow –design equations for convective mass transfer – analysis between momentum, heat and mass transfer.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Select suitable criteria for solving material and energy balance problems
CO2: Analyze and assess solutions to equation of motion.
CO3: Apply appropriate methods for problems in conductive heat transfer.
CO4: Value convective heat transfer process and in the design of heat exchangers.
CO5: Judge the importance of mass transfer and compare the analogy between heat, mass and momentum transport processes.

REFERENCE BOOKS:

1. R. Byron Bird, Warren E. Stewart and Edwin N. Lightfoot, “Transport Phenomena”, 2nd edition, John Willey & Sons, 2006.
2. C.J.Geankoplis, “Transport Processes and Unit Operation”, 3rd edition, Prentice Hall,1993.

3. J.R.Welty, C.E. Wicks, G. L. Rorrer and R.E.Wilson, “Fundamentals of Momentum, Heatand Mass transfer”, 5th edition, John – Wiley & Sons, New York, 2007.
4. C.J. Geankoplis, “Transport Processes – Momentum, Heat and Mass”, (Allyn andBaconInc), Boston, USA 1983.
5. Robert Ewald Treybal, Mass-transfer Operations,McGraw-Hill, 1980

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	2	2	2	1	-
CO2	1	2	2	2	1	-
CO3	2	2	2	2	1	2
CO4	2	2	2	2	1	2
CO5	2	2	2	2	1	-
Average PO	1.6	2	2	2	1	2

PL3203 PROCESS CONTROL IN POLYMER INDUSTRY L T P C
3 0 0 3

OBJECTIVES:
To prepare the students to
- Compare the process variables and their measurement.
- Value the controllers used in polymer industries.
- Justify knowledge on computer control and applications.
- Simplify the concepts of instrumentation involved in injection and blow moulding.

UNIT I PROCESS VARIABLES **8**
Process variables such as temperature, pressure, flow etc., and their measurements. Examples in polymer processing in moulding and extrusion.

UNIT II MEASUREMENT AND CONTROL **10**
Measurement and control – Simple systems-first and higher order systems- Design specifications on system time response – feedback control diagram – proportional, integral, derivative and PID controls.

UNIT III MATHEMATICAL ANALYSIS **10**
Mathematical analysis of processes and feedback control systems – poles, zeros and system stability - Stability Analysis - Routh’s Test-Root locus-frequency response using Bode plot.

UNIT IV COMPUTER CONTROL **8**
Computer control and application – mathematical concepts of discrete variables analysis and multivariable processes and other control methods as feed forward control, ratio control and internal model control etc.

UNIT V INSTRUMENTATION **9**
Instrumentation in blow moulding, extrusion and injection moulding and control systems.

TOTAL: 45 PERIODS

COURSE OUTCOMES:
At the end of the course, students will be able to
CO1: Describe the various process variables and their measurements.
CO2: Identify physical examples for first and second order systems and choose appropriate systems for practical applications.
CO3: Simplify the concepts of control system stability and assess different methods to

arrive at it.

CO4: Apply computer control methods to solve problems in stability analysis.

CO5: Explain the instrumentation concepts in blow, injection and extrusion moulding.

REFERENCE BOOKS:

1. Steven E. LeBlanc and D.R.Coughanour, "Process Systems Analysis and Control", McGrawHill Book Co., 3rd Edition, 2009.
2. D.M. Considine, "Process/Industrial Instruments & Controls Handbook", 4th edition, McGraw-Hill Inc., New York (1993).
3. D.V.Rosato, "Blow Moulding Hand book", 2nd edition, Hanser Publications, 2004.
4. A.Whelan, "Developments in Injection Moulding", Applied Science Publications,1989.
5. Sidney Levy, "Plastic Extrusion Technology Hand Book", Industrial Press Inc.,NewYork,1989.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1	1	2	1	1	1
CO2	1	1	2	1	2	2
CO3	1	1	1	1	2	1
CO4	1	1	1	1	2	1
CO5	1	1	1	1	2	2
Average PO	**1**	**1**	**1.6**	**1**	**1.8**	**1.4**

PL3204 POLYMER PRODUCT AND MOULD DESIGN L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Relate polymer product and mould design.
- Appreciate the design concepts of mould and die
- Design extrusion and injection mould dies
- Compare the design concepts in compression and transfer moulding.

UNIT I BASIC CONCEPTS OF PRODUCT DESIGN 9

Mould material selection - polymeric material and its processing effects on performance of parts and its limitation on product design - polymeric product design concept - design of radii, fillets, ribs and bosses, design of parting line, wall thickness, Moulded holes - drilled and tapped holes, taper or draft - design of hinges and snap for boxes - feed system - sprue, runner & gate - ejector system - mould vent - venting method - external & internal undercuts - Moulded threads – thread types - threaded holes - assembly - fits & tolerances.

UNIT II POLYMERIC PRODUCT DESIGN 9

Structural design of beams, columns, plates, bars, pipes and shells - design procedure for polymeric parts - design of plastic structural parts for static and dynamic load - gears and bearings design - design of plastic parts for electrical and optical applications - basic design configuration for elastomeric seals and rings - Concepts of composite product design.

UNIT III INJECTION MOLD DESIGN 10

Introduction - process variables - moulding cycle - General mould construction - core, cavity, guide pillar, feed system & ejection system and techniques -Two plate mould - Stripper plate mould - three plate mould-single impression and multi- impression - split moulds - finger cam and dog-leg cam actuation mould-inserts – Selection of metal for inserts - side cores and side cavities -split cores- relieving moulding stress around inserts - flow characteristics - injection pressure -injection speed- hold on time- gate freezing - clamping force calculation -

temperature control system - cooling system.

UNIT IV EXTRUSION DIE DESIGN 9

Principle of Extrusion - Important aspects of die design - basic geometry of die - die land design - die swell - construction of extrusion die – blown film, pipe, profile - sheet, flat film, tube, wire/cable coating dies, co-extrusion die - spiral mandrel die, fish tail die, adjustable core die - extrusion die for rubber parts - heating system - temperature control - effect of temperature and pressure on die design.

UNIT V OTHER MOULD DESIGNS 8

Compression mould, principles, types - designing of open flash, positive and semi-positive, and displacement moulds, types of loading chambers, bulk factor, flash thickness, projected area, compression pressure, clamping force. transfer mould design, principles, types - pot and plunger - projected area, transfer pressure, clamping force, pressure pad design, flash thickness, bulk factor - design of sprue runner and gate, blow moulds - types - parison and pinch off design -rotational mould design.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Relate the basic concepts of product design.
CO2: Apply design aspects based on the type of polymer and its applications.
CO3: Analyze the design aspects of various plastic parts by injection moulding.
CO4: Assess the die design of plastic parts prepared by extrusion moulding.
CO5: Design mold/die for different molding process.

REFERENCE BOOKS:

1. Harold Belofsky, “Plastics Product Design and Process Engineering”, SPE,HanserPublication, 1995.
2. Sanjay K Nayak, “Fundamentals of Plastics Mould Design”, 1st edition, Mcgraw Hill, NewDelhi, 2012.
3. J.Y.H. Fuh, “Computer-Aided Injection Mold Design and Manufacture”, 1st edition, CRC-Taylor and Francis group, 2004.
4. Dym J.B, “Injection Mould & Moulding, A practical Manual”, 2nd edition, Springer, 1987.
5. Hopmann, Michaeli, “Extrusion dies for plastics and rubbers”, 4th edition, Hanser publication, 2016.
6. Robert A. Malloy, “Plastic Part Design for Injection Moulding”, Hanser Pub., MunichViennaNY, 1994.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	2	1
CO2	1	1	1	2	2	2
CO3	1	1	1	1	2	2
CO4	1	1	1	1	2	2
CO5	1	1	1	1	2	2
Average PO	1	1	1	1.2	2	1.8

PL3211 POLYMER ANALYSIS AND CHARACTERISATION LAB L T P C
0 0 4 2

OBJECTIVES:

To prepare the students to

- Identify the plastics and rubber materials.
- Experiment the structural and electrochemical properties of polymers.
- Formulate the composition of the polymer product.
- Interpret the data obtained from various analytical techniques.

UNIT I IDENTIFICATION 20

Identification of plastics - PP, PE, polyamide, polyester, PVC, NBR, PS, ABS, PC, IIR, SBR, Thiokol, CR, Butyl rubber, etc.

UNIT II ANALYSIS METHODS 20

MFI, Brookefield viscometer - oxygen index - filler content determination (muffle furnace) - determination of carbon black content - density measurement, electrochemical analysis - cyclic voltammetry, chronopotentiometry, chronoamperometry.

UNIT III INTERPRETATION 20

Surface morphology study – SEM, Interpretation of DSC, TGA, IR and NMR.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Identify the polymeric materials.

CO2: Determine the filler and carbon black content and assess the electro-chemical properties of polymers.

CO3: Formulate the composition of the polymer product.

REFERENCE BOOKS:

1. Dietrich Braun, "Simple Methods for identification of plastics", 5th edition, 2013.
2. Campbell and J. R. White, "Polymer Characterization Physical Techniques", ChapmanandHall, London, 1989.
3. Charles L. Rohn, "Analytical Polymer Rheology", Hanser Publishers, Munich, 1995.
4. Edith A. Turi, "Thermal Characterization of Polymeric Materials", 2nd edition 1997.
5. J. Spells, "Characterization of Solid Polymers", Chapman and Hall, London, 1994.
6. T.R. Crompton, "Characterization of Polymers", volume 1 and 2, Smithers Rapra Technology Limited, 2008.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	2	2	1
CO2	1	1	2	2	1	1
CO3	2	1	2	2	1	1
CO4	--	--	--	--	--	--
CO5	--	--	--	--	--	--
Average PO	1.6	1	2	2	1.3	1

PL3212 MOULD DESIGN AND ANALYSIS LAB L T P C
0 0 4 2

OBJECTIVES:

To prepare the students to

- Design and develop mould and die.
- Analyze the injection mould design
- Construct mould flow simulation and FEA
- Evaluate rapid prototyping and PLC

UNIT I BASIC MODELING AND DRAFTING 12

2D drawing and drafting (2 drawings) using software- 3D modeling and drafting using software (3 models) - Assembling and drafting (2 assemblies) - Surface modeling (2 exercises) - 2D and 3D modeling of plastic components.

UNIT II INJECTION MOULD DESIGN 12

Mold design concept- Fixed clamping plate, cavity plate, back plate, ejector retainer plate, ejector back plate, movable clamping plate, runner, gate, side cores and its assembly -Design calculation for number of cavities, plasticizing rate, clamping force - 2D, 3D designing and modeling of single cavity mould, Multi cavity mould, split mould.

UNIT III MOULD/DIE DESIGN 12

2D, 3D designing and modeling of compression, transfer moulds - calculation of clamping force, flash thickness allowance - 2D, 3D designing and modeling of blow moulds - calculation of pinch off, head die design, parison dimension- 2D, 3D designing and modeling of extrusion die.

UNIT IV FLOW ANALYSIS 12

Design and process parameter optimization - Mold flow simulation - finite element analysis, meshing - Mold flow analysis- Fill analysis, pack analysis, cool analysis, warp analysis, shrinkage analysis, gate location analysis, wall thickness analysis, runner balance analysis, stress analysis.

UNIT V PRODUCT LIFE CYCLE AND PROTOTYPING 12

Programs on PLC for plastic products (3-5 programs) – solid free form manufacturing and Reverse Engineering.

TOTAL: 60 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Assemble and draft components in 2D and 3D models
CO2: Discuss the design of complicated parts in injection moulding.
CO3: Design and develop any type of mould and die for plastic products.
CO4: Analyze the flow behavior using mould flow analysis
CO5: Evaluate the concepts of PLC and rapid prototyping.

REFERENCE BOOKS:

1. "Design calculations for Compression moulds", Machinery publications, Yellow series, U.K.
2. Herbert Rees, "Mould Engineering", Hanser publishers, Munich, Vienna N.Y. 1994.
3. Jay Shoemaker, "Moldflow Design Guide: A Resource for Plastics Engineers", Volume10,1st edition, Mold flow corporation, 2006
4. LaszcoSors and ImreBlazs, "Design of Plastic Moulds and Dies", Elsevier, Amsterdam -Oxford - Tokyo - NY, 1989.
5. "Mould Flow Manual & Part - Adviser Manual" - MOULD FLOW.
6. Max Giordano, Luc Matheiu and Francois Villeneuve, "Product Lifecycle Management -Geometric Variations", Wiley, 2013.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	2	2
CO2	1	1	1	1	2	2
CO3	1	1	1	1	2	2
CO4	1	1	1	1	2	2
CO5	1	1	1	1	2	2
Average PO	**1**	**1**	**1**	**1**	**2**	**2**

PL3312 **PROJECT WORK I** **L T P C**
0 0 12 6

OBJECTIVES:
The course aims to enable the students to identify the research problem relevant to their field of interest, search databases to define the problem, design experiment, conduct preliminary study and report the findings.

COURSE CONTENT
Individual students will identify a research problem relevant to his/her field of study with the approval of project review committee. The student will collect, and analyze the literature and design the experiment. The student will carry out preliminary study, collect data, and interpret the result, prepare the project report and present before the committee.

TOTAL: 180 PERIODS

OUTCOMES:
At the end of the course the students will be able to
CO1: Identify the research problem
CO2: Collect, analyze the relevant literature and finalize the research problem
CO3: Design the experiment, conduct preliminary experiment, analyze the data and conclude
CO4: Prepare project report and present

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
Average PO	3	3	3	3	3	3

PL3411 **PROJECT WORK II** **L T P C**
0 0 24 12

I. Continuation of Project Work I (at Institution/Industry)

OBJECTIVES:
The course aims to enable the students to conduct experiment as per the plan submitted in Project work I to find solution for the research problem identified.

COURSE CONTENT
The student shall continue Project work I as per the formulated methodology and findings of preliminary study. The student shall conduct experiment, collect data, interpret the result and provide solution for the identified research problem. The student shall prepare the project report and present before the committee.

TOTAL: 360 PERIODS

OUTCOMES:
At the end of the course the students will be able to
CO1: Conduct the experiment and collect data
CO2: Analyze the data, interpret the results and conclude
CO3: Prepare project report and present

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
Average PO	3	3	3	3	3	3

II. Not the continuation of Project Work I (at Industry)

OBJECTIVES:
The course aims to enable the students to identify the research problem at the company, search databases to define the problem, design experiment, and conduct experiment to find the solution.

COURSE CONTENT
Individual students will identify a research problem relevant to his/her field of study at the company and get approval of project review committee. The student will collect, and analyze the literature and design the experiment. The student will carry out the experiment, collect data, interpret the result, prepare the project report and present before the committee.

TOTAL: 360 PERIODS

OUTCOMES:
At the end of the course the students will be able to
CO1: Identify the research problem
CO2: Collect, analyze the relevant literature and finalize the research problem
CO3: Design and conduct the experiment analyze the data and conclude
CO4: Prepare project report and present

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
Average PO	3	3	3	3	3	3

PL3001 ADDITIVES AND COMPOUNDING OF PLASTICS **L T P C**
3 0 0 3

OBJECTIVES:
To prepare the students to

- Compare the additives like Antioxidants, Metal deactivators Lubricants, Fillers, fibres, flame retardants, colorants, anti-oxidants, Antistatic agents etc.
- Value the functions of each of these additives, technical requirements,
- Evaluate the additive types and their mechanism.
- Discuss compounding techniques and Equipments.

UNIT I ADDITIVES **11**
Introduction to additives- Classification of additives- need and function of additives- Antioxidants, Mechanism, requirements and testing- Metal Deactivators – Mechanism of inhibition, requirements, structural classes and testing – Light Stabilizers – Photo oxidation scheme, Mechanism of stabilization and testing – Plasticizers theories of plasticizing–Nucleating agents - Lubricants – Anti sliping agent – Antistatic agent – antiblocking agents – blowing agent – flame retardant – toughening agent.

UNIT II COLORANTS AND COLORING TECHNOLOGY 9

Optical principles and phenomena – Metamerism, Dichroism – General properties, Colorants – White pigment, Black colorants, Inorganic colorants – Oxidic colored pigments, hydroxyl pigments, sulfidic pigments, chromates – Organic colored pigmets- azo pigments, non azo pigments – Coloring technology – Selection criteria, Dispersion, break down, wetting, distribution, cohesive forces- coloration techniques – Coloration with pigment powders, coloration with pigment concentrates.

UNIT III FILLERS AND REINFORCEMENT 9

Theories and action of fillers and reinforcement- properties of filled and reinforced plastics – Economical importance – Description of filler and reinforcements – Calcium Carbonate, Dolomite, Silicates, Talc, Kaolin, Mica, Feldspar, Wollastonite, metal and metal oxides Carbon, carbon black, graphite, basalt fiber, carbon fiber, sisal fiber, boron fiber, electrically conducting fillers.

UNIT IV COMPOUNDING TECHNIQUES 7

Selection criteria of polymers and compounding ingredients - General objectives - possibilities and limitations of mixing and compounding-Principle of mixing and compounding - Methods of incorporation of additives into polymer materials.

UNIT V COMPOUNDING EQUIPMENTS 9

Mixing and mixing equipment's. Principles- Operating characteristics- Machine construction-Specifications -Process control systems and working details of Batch mixers and continuous mixers - High speed mixer -Two roll mill-Banbury Mixer-Ribbon blender - twin drum tumbler -Z blade mixer - Planetary mixers-Single Screw extruder-Twin Screw extruder.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Compare various additives and choose them as per requirement in polymeric industries
CO2: Value colourant and colouring technology and its use in polymer industries
CO3: Identify the required fillers and reinforcements for specific applications.
CO4: Discuss the compounding techniques.
CO5: Select suitable compounding equipments as per requirement.

REFERENCE BOOKS:

1. R. Gachter and H.Muller, "Plastics additive handbook", 4th edition, Hanser publications, 1993
2. Manas-Zloczower, "Mixing and Compounding of Polymers", 2nd edition,Hanser Publications,2009.
3. J.A.Brydson, "Plastics Materials", 8th edition, Butterworth Heinemann, Oxford, 2016.
4. Mascia; L, "The Role of Additives in Plastics", John Wiley & Sons,1974
5. Ernest W. Flick, "Plastics Additives", vol - 2, 1st edition, William Andrew,2001.
6. Murphy John, "Additives for Plastics Handbook", 2nd edition, Elsevier Science,2001.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	2	-	-
CO2	3	1	3	2	-	-
CO3	3	-	3	2	2	-
CO4	3	1	3	2	3	-
CO5	3	1	3	2	3	-
Average PO	3	1	3	2	2	-

PL3002 ADDITIVE MANUFACTURING L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Describe the technology of additive manufacturing for plastics products.
- Execute the additive manufacturing process and applications.
- Interpret the design concepts in additive manufacturing.
- Compare various software tools, processes and techniques to create physical objects that satisfy product development / prototyping requirements, using AM.

-

UNIT I INTRODUCTION 9

Introduction to Additive Manufacturing (AM)- AM evolution, Reverse engineering- Distinction between AM & CNC machining, Advantages of AM; AM process chain – Classification – Applications. Case studies: Bio printing- Food Printing- Electronics printing - Building printing.- Selection of AM technologies using decision methods – AM process plan & supply chain.

UNIT II ADDITIVE MANUFACTURING (AM) TECHNOLOGIES 12

Powder based, droplet based, extrusion based - Object Stereo lithography - Principle, pre-build process, part-building and post-build processes, photo polymerization of SL resins - Solid Ground Curing (SGC)- Fused deposition Modeling (FDM) - Laminated Object Manufacturing (LOM) - Selective Laser Sintering (SLS) -Laser Engineered Net Shaping (LENS) - Shape Deposition Manufacturing (SDM) - Ballistic Particle Manufacturing (BPM).

UNIT III MATERIALS FOR AM 6

Multi-functional and graded materials in AM - Role of solidification rate - Evolution of non-equilibrium structure - structure property relationship.

UNIT IV DESIGN FOR ADDITIVE MANUFACTURING (DFAM) 9

DFAM concepts and objectives, AM unique capabilities, Part Consolidation-Topology Optimization Light weight Structure - DFAM for Part Quality Improvement. Data Processing - CAD Model Preparation -Part Orientation and Support Structure Generation -Model Slicing - Tool Path Generation - Customized Design and Fabrication for Medical Applications- Case Studies.

UNIT V APPLICATIONS AND POST PROCESSING 9

Direct processes; Rapid prototyping, Rapid tooling, Rapid manufacturing – Indirect processes; Indirect prototyping, indirect tooling, indirect manufacturing - Application examples for Aerospace, defense, automobile, Bio-medical and general engineering industries. Post processing of AM parts: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Interpret the concepts of AM, AM technologies
CO2: Select suitable Additive Manufacturing (AM) method.
CO3: Compare the selection of materials for AM
CO4: Execute the research challenges associated with AM and its data processing tools.
CO5: Discuss the AM process plan including building strategies and post processing.

REFERENCE BOOKS:

1. Andreas Gebhardt and Jan-Steffen Hötter “Additive Manufacturing: 3D Printing forPrototyping and Manufacturing”, Hanser publications, United States, 2015, ISBN: 978-1- 56990-582-1.
2. IanGibson, David W.Rosen and Brent Stucker “Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing”, 2nd edition, Springer., United States, 2015, ISBN-13:978-1493921126.

3. Adedeji B. Badiru, Vhance V. Valencia , David Liu, " Additive Manufacturing Handbook "CRC Press,2017.
4. Amit Bandyopadhyay and Susmita Bose, “Additive Manufacturing”, 1st Edition, CRC Press., United States, 2015, ISBN-13:978-1482223590.
5. Kamrani A.K. and Nasr E.A., “Rapid Prototyping: Theory and practice”, Springer., United States, 2006, ISBN:978-1-4614-9842-1.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	2	3	-
CO2	3	-	2	2	3	-
CO3	3	1	2	2	3	-
CO4	3	1	2	2	3	3
CO5	3	-	2	2	3	3
Average PO	**3**	**1**	**2**	**2**	**3**	**2**

PL3003 ADHESIVE AND COATING TECHNOLOGY L T P C 3 0 0 3

OBJECTIVES:

To prepare the students to

- Differentiate the surfaces on energy and morphology.
- To analyze the theoretical and technological aspects of mechanism and characterization of adhesives.
- To compare and contrast the various types of Adhesives employed in Industries.
- To apply the adhesives in various fields.

UNIT I ADHESION MECHANISM 9

Definition and mechanisms of adhesion - mechanical interlocking – inter-diffusion theories – adsorption and surface reaction. Surface topography, surface features and forces, wetting and setting, thermodynamic work of adhesion– influence of constitution on adhesion – interfacial bonding – coupling agents.

UNIT II CHARACTERIZATION OF ADHESIVES 9

Principle of fracture mechanics, peel, lap sheen and butt tensile tests. Pull out of an extendable fiber, various testing and evaluation of adhesives, energy dissipation – plasticity – strength of elastomers.

UNIT III COATINGS TECHNOLOGY 9

Introduction to coatings, Types of coatings, Need of Polymers in coatings, Advantages and limitations of Conventional coatings, Need of Bio-based coatings, Conventional vs. Bio-based coatings, Chemistry, Fabrication techniques, Characterization techniques, Polymer coatings applications in automotive, aerospace, marine, defense and textile, automotive graphics- Case studies. Inorganic adhesives. Principle of compounding – role of resins – fillers – antioxidants – accelerator systems

UNIT IV ADHESIVE TYPES 9

Adhesive from natural origin - animal glues – casein – starch – cellulosic and bio adhesives. Synthetic adhesives - phenolic resin, epoxy, polysulphide, polyurethane, polyvinyl acetate, polyvinyl alcohol, polyvinyl acetal, acrylics, high temperature silicone adhesives. Water based – pressure sensitive – hot - melt adhesives – anaerobic adhesives.

UNIT V APPLICATIONS OF ADHESIVES 9

Adhesives for building construction, medical use, automobile industry bonded and coated abrasives – fabrics, cyanoacrylate based adhesives, bonding technology for textile, metal, plastics, wood, paper and glass.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1:Analyze different adhesives and mechanism of adhesion.
CO2: Differentiate the various testing methods for adhesives and coatings
CO3: Execute coatings in various fields.
CO4:.Organize the utility of adhesives in industry
CO5: Apply adhesives on various fields.

REFERENCE BOOKS:

1. Frank N. Jones, Mark E. Nichols, Socrates Peter Pappas, Organic Coatings: Science and Technology, 4th Edition,2017
2. P. Ghosh, “Adhesives and Coatings Technology”, Tata-McGraw-Hill Publishing Company Limited, New Delhi,2008.
3. A.V. Pocius, “Adhesion and Adhesives Technology”, Hanser,2002
4. W. A. Lees, “Adhesives in engineering design”, Springer Verlag, Berlin,1984.
5. D.M. Brewis and D. Briggs, “Industrial adhesion problems”, Wiley-Interscience Publication, New York,1985.
6. A. J. Kinloch, “Adhesion and Adhesive Science and Technology”, Springer,1987.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	-	3	-
CO2	3	-	3	1	3	3
CO3	3	1	3	1	3	3
CO4	3	-	3	-	3	3
CO5	3	1	3	1	3	3
Average PO	3	1	3	1	3	3

PL3004 BIOPOLYMERS ANDBIODEGRADABLE POLYMERS L T PC
3 0 0 3

OBJECTIVES:

To prepare the students to

- Compare biodegradable polymers and the degradation mechanisms.
- Differentiate the principles of biodegradation in liquid and soil.
- Compare the structures and applications of biopolymers.
- Select the biopolymer processing techniques and its application in packaging.
- Value the structure and functions of natural biopolymers and their applications.

UNIT I BIODEGRADABLE POLYMERS 9

Introduction, Advantages, Classification; Degradation of polymers – Mechanism - Thermal degradation, Mechanical Degradation, Degradation by Ultrasonic Waves, Photo degradation, Degradation by High Energy Radiation, Oxidative Degradation and Hydrolytic Degradation; Biological Degradation - Enzymic Hydrolysis, Enzymic Oxidation; Analysis of Biodegradation - Enzyme assays, Plate test, Respiratory test, Natural environment, Field trial, Gas evolution test, Factors Affecting Biodegradability.

UNIT II BIODEGRADATION OF POLYMER IN LIQUID AND SOIL 9

Biodegradation in Liquid Environments - Degradation in real & laboratory Tests - Simulating real aquatic environments, Defining and optimizing liquid media; Standard tests using liquid media,

Biodegradation behavior of polymers in the soil - The soil environment - Surface factors, underground factors, Degradability of polymers in soil, Effects of biodegradable polymers on Soil Living Organisms.

UNIT III GREEN CHEMISTRY FOR POLYMERS 9

Sustainability of Petroleum resources – Need for Alternate Sources for Polymers - Polymer Recycling and Environmental Issues – Need for biodegradation of packaging materials – Introduction to Life Cycle Assessment – Monomers from biosources. Structure and chemical composition - Biopolymer Films – Biodegradable mulching – Advantages and Disadvantages – Chemical sensors – Biosensors – Functionalized Biopolymer Coatings and Films.

UNIT IV BIOPOLYMERS 9

Types of Biodegradable Polymers - Bio based polymers, starch based polymers, cellulose based polymers, chitin and chitosan, bacterial polyesters, synthetic biodegradable polymers, polymers from bio based monomers - Proteins, hemicellulose and cellulose based biopolymers - Plant and animal based proteins – Solution casting of proteins – Processing of proteins as plastics – preparation and properties of hemicellulose – Cellulose based composites - Surface and chemical modifications of cellulose fibers.

UNIT V STRUCTURE OF BIOPOLYMERS 9

Natural Polymers: chemical & physical structure, properties, source, important chemical modifications, applications of polymers such as cellulose, lignin, starch, rosin, shellac, latexes, vegetable oils and gums, proteins.– the macromolecular structure and biological functions of polymers - primary, secondary, tertiary and quaternary structure of polymers – structure maintenance and transmission of the biological information- viruses and phages – living macromolecules.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Compare the nature of biodegradable polymers and the degradation mechanisms.
CO2: Differentiate knowledge on principles of biodegradation in liquid and soil.
CO3: Evaluate the structures and applications of biopolymers.
CO4: Select biopolymer processing techniques and its application in packaging.
CO5: Value the structure and functions of natural biopolymers and their applications.

REFERENCE BOOKS:

1. Handbook of Biopolymers and Biodegradable Plastics, A volume in Plastics Design Library, Edited by: Sina Ebnesajjad, 2013 Elsevier
2. Biopolymers Towards Green and Sustainable Development, Sudarshan Singh, Warangkana Chunglok, Bentham books,2022.
3. Jens Nielsen, John Villadsen and Gunnar liden, “Bioreaction Engineering Principles”, 3rd edition, Springer 2011.
4. Charles Gebelein, Biotechnological Polymers: Medical, pharmaceutical and industrial applications, CRC press,1993.
5. Himadri Panda, Modern Technology of Biodegradable Plastics and Polymers with Bio-Plastics, Starch Plastic, Cellulose Polymers & Others, Engineers India Research Institute, 2015.
6. Manjari Sharma , "Bio-degradable Polymer Compositions Materials and their Structures" Manakin Press 2015.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	1	-	-
CO2	2	1	3	-	-	-
CO3	2	1	3	1	-	-
CO4	2	1	3	1	-	-

CO5	2	1	3	-	-	-
Average PO	2	1	3	1	-	-

PL3005 CAD/CAM APPLICATION IN MOULD/TOOL DESIGN L T P C
3 0 0 3

COURSE OBJECTIVES:

To prepare the students to

- Explain computer aided design and computer aided manufacturing.
- Implement CAD/CAM in designing of plastics moulds,
- Execute CAD/CAM applications in tool designing.
- Discuss evolution, types and principles of CNC machine tools
- Design manual part program and generation of CNC part program

UNIT I INTRODUCTION 9

Basic concepts of CAD - graphic primitives, curve representation, windowing, clipping - shape and size description- parametric programming – interactive programming (LISP)- 2D drafting - 3D modeling- surface and solid modeling - assembly modeling.

UNIT II GRAPHICS AND DATABASE 9

Computer graphics – Graphical Kernel System (GKS), - Open Graphics Library (Open GL)- Concept of Engineering database - Database Management– Data exchange standards – STEP, IGES, CALS, ACIS and DXF - communication standards.

UNIT III CNC 9

Evolution of CNC Technology - principles - features - advantages – applications - Numerical control (NC), Computer Numerical control (CNC), Direct Numerical Control (DNC) - Coordinate system - structure of a CNC part program - Part programming – G Codes & M Codes - Working principle of CNC machines – CNC milling, CNC turning, CNC EDM machining- CNC simulation – CNC interface with CAD- Programming for machining centre and turning centre for well-known controllers.

UNIT IV AM, CIM & FEA 9

Introduction to CAM softwares - advanced CAD/CAM technology – Flexible manufacturing system (FMS) – Computer Integrated manufacturing (CIM) – Finite element analysis – nodes and meshes Types of analysis.

UNIT V MOULD FLOW ANALYSIS 9

Computer aided engineering (CAE) - Introduction to Mould flow analysis - mould flow concepts - analysis sequence - optimizing design and defects - Flow analysis - Thermal analysis - Warpage Analysis - Cooling Analysis - Shrinkage Analysis – Pressure Analysis.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Implement basic graphic primitives, 2D drafting and 3D modeling
CO2:.Manage the database.
CO3: Execute CNC, FEM, etc.,
CO4: Explain Computer Aided Design and Computer Integrated manufacturing (CIM)
CO5: Analyze mould flow characteristics.

REFERENCE BOOKS:

1. Chris McMahon and Jimmie Browne “CAD/CAM Principles", "Practice and Manufacturing management “Second Edition, Pearson Education,1999.
2. Donald Hearn and M. Pauline Baker “Computer Graphics”. 2nd edition, Pearson educationIndia.,2002.
3. Ibrahim Zeid “Mastering CAD CAM” 2nd edition, Tata McGraw-Hill PublishingCo.2007.

4. Jay Shoemaker “Mold flow Design Guide: A Resource for Plastics Engineers”, Volume 10,4th edition, Hanser,2006.
5. Radhakrishnan, P. & Subramanyan. S, “CAD/CAM/CIM”,2nd Edition, internationals, 2008.
6. Rao P N, Tiwari N K, Kundra T, “Computer Aided Manufacturing” TataMcGraw.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	3	2	3	2
CO2	3	1	3	2	3	-
CO3	3	1	3	2	3	-
CO4	3	-	3	2	3	-
CO5	3	-	3	2	3	-
Average PO	3	1	3	2	3	-

PL3006 COMPOSITES TECHNOLOGY L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Compare and contrast various types of reinforced plastics and its advantages and needs.
- Select various types of fibers, resins and other additives materials available for making composites.
- Develop expertise in the various types of moulds, premix moulding compounds and processes used in the processing of composites
- Design destructive and non-destructive testing of reinforced plastics
- Formulate concepts of nano reinforcements, their types , processing of nano reinforced plastics and their applications

UNIT I INTRODUCTION TO COMPOSITES 9

Characteristics, advantages, and need for reinforced plastics – Classification – particulate, fibrous, laminated, PMC, MMC, CMC, advanced, hybrid, braided and carbon matrix composites. Predicting properties of Fiber-Reinforced composites.

UNIT II MATRIX MATERIALS 9

Fibers: Glass –Types (E,S&C),roving, yarns, CSM, surface mats, preforms, woven and nonwoven fabrics - Three dimensional fabrics (woven, knitted and braided); Carbon – PAN and Pitch based - HT, HM and IM; Aramid – Kevlar, Technora HM-50; Production, properties and applications. Natural fibers. Surface treatments. Resins : Thermosets - Unsaturated polyester, epoxy, vinyl ester, silicones & polyimides – production, properties and applications; Thermoplastics - Examples, Comparison with thermosets. Nanofillers Properties andapplications.

UNIT III PROCESSING OFCOMPOSITES 9

Different types of molds - DMC, SMC and prepregs. Hand & Spray layup- Bag, autoclave, centrifugal molding, RTM, Vacuum infusion, pultrusion, filament winding, compression molding process and sandwich construction.

UNIT IV TESTING OF COMPOSITES 9

Fiber volume fraction, tensile, shear, compressive, flexural, thermo elastic and off – axis responses of lamina and laminates - notched strength – fracture toughness – nondestructive testing.

UNIT V POLYMER NANOCOMPOSTIES 9

Introduction: Nanoscale Fillers – Clay, POSS, Carbon based nanomaterials, nanoparticle fillers; Processing into nanocomposites; Modification of interfaces; Properties. Applications.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Compare the composites and discuss its advantages

CO2: Evaluate various types of fibers and polymers to prepare composites.

CO3: Develop expertise on the processes to prepare composites and will be able to choose suitable process as per product requirement.

CO4: Design quality control tests and evaluate suitability of the composite products for various applications.

CO5: Construct composite products for various applications.

REFERENCE BOOKS:

1. George Lubin, Stanley T. Peters, Handbook of Composites, Chapman & Hall,1998.
2. BorZ.Jang, Advanced Polymer composites, ASM International, USA,1994.
3. Mel M. Schwartz, Composite Materials: Processing, fabrication, and applications, Prentice Hall PTR,1997.
4. M.C.Gupta and A.P.Gupta, Polymer Composites, New Age International Publishers, 2007.
5. LeifA. Carlsson, Donald F.Adams, R.ByronPipes, Experimental Characterization of advanced composite materials, Fourth Edition, CRC Press, 2014.
6. Emmanuel Craig, Nanocomposites: Fundamentals, Technology and Applications 2017, Larsen and Keller Education.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	3	2
CO2	3	1	2	2	3	2
CO3	3	1	2	2	3	1
CO4	3	-	2	2	3	-
CO5	3	2	2	2	3	1
Average PO	3	2	2	2	3	2

PL3007 CONDUCTING POLYMERS L T P C

3 0 0 3

OBJECTIVES:

To prepare the students to

- Execute doping and conductivity in polymers
- Demonstrate processing and applications of conducting polymers.
- Compare electrochemical, spectral and morphological characterization of conducting polymers
- Fabricate device using conducting polymers.

UNIT I ELECTROCHEMISTRY OF CONDUCTING POLYMERS 9

Theory of conduction-band theory; requirements for polymer to work as conductor; types of conducting polymers-intrinsic and extrinsic; source of electronic conduction in polymers - solitons, polarons and bipolarons; doping; factors affecting conductivity; measurement of conductivity-Vander Pauw technique.

UNIT II SYNTHESIS, PROCESSING AND APPLICATIONS OF CONDUCTING POLYMERS 9

Synthesis of conducting polymers - chemical and electrochemical methods; synthesis, processing and applications of polyacetylene, polyaniline, polypyrrole, polythiophene and poly-para

phenylene based conducting polymers.

UNIT III ELECTROCHEMICAL CHARACTERIZATION OF CONDUCTING POLYMERS 9

Electro-analytical techniques - cyclic voltammetry, chronoamperometry and chrono-coulometry

UNIT IV SPECTRAL AND MORPHOLOGICAL CHARACTERIZATION OF CONDUCTING POLYMERS 9

FTIR, UV-vis, Raman, XRD, SEM, TEM, DETA, TGA, DTA, DSC and DMA.

UNIT V DEVICE FABRICATION 9

Rechargeable batteries, solar cells, light emitting devices; microelectronics-PCB fabrication; antistatic coating, EMI shielding, functionalized bio-conductive polymers- sensors and actuators; super capacitor; super conductor (Inorganic, organic hybrid structure), composites of conducting polymers

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Distinguish principle and mechanism of conducting polymers along with the concept of doping.
CO2: Synthesize a conducting polymer and discuss its applications.
CO3: Evaluate the electro-chemical properties of conducting polymer.
CO4: Analyze and describe the spectral properties of conducting polymers.
CO5: Apply the knowledge of conducting polymers and construct devices for energy storage.

REFERENCE BOOKS:

1. T.A. Skotheim, R.L. Elsenbaumer and J.R. Reynolds, "Hand book of Conducting Polymers", 2nd Edition, Revised and enlarged, Marcel Dekker Inc., New York, 2007.
2. J.M. Margolis (Ed.), "Conducting Polymers and Plastics", Springer, 2011.
3. R.B. Seymour, "Conductive Polymers", 2nd edition Plenum Press, New York, 1981.
4. B. Wessling, "Electronic Properties of Conjugated Polymers", Vol.3, Springer, Berlin, 1989.
5. H.G. Kiess (Edr.), "Conjugated Conducting Polymers", Springer, Berlin, 1992.
6. D.S.Soane and Z Martynenko (Eds.),"Polymers in Microelectronics", Elsevier, Amsterdam, 1989.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	2	1	3	2	2
CO2	3	2	3	3	2	1
CO3	3	2	3	2	2	2
CO4	3	2	3	2	2	2
CO5	3	2	2	2	2	3
Average PO	**3**	**2**	**2.4**	**2.4**	**2**	**2**

PL3008 HIGH PERFORMANCE POLYMERS L T P C 3 0 0 3

OBJECTIVES:

To prepare the students to

- Relate high performance polymers and its applications.
- Apply the polymers in energy storage devices.
- Select polymers for lithography and water treatment.
- Develop polymers to use in bio-medical field.

UNIT I POLYMERS FOR ELECTRICAL AND ELECTRONICS APPLICATIONS 9

Engineering plastics - polymers in electrical and electronics industry - electro conducting polymers polymer batteries - electrets - polymers with piezoelectric, pyroelectric and ferroelectric properties photo conducting polymers.

UNIT II POLYMERS FOR HIGH TEMPERATURE APPLICATIONS 9

Polymers for high temperature resistance - fluoro polymers, aromatic polymers, heterocyclic polymers; polymers as building materials; aramids and carbon fibres.

UNIT III POLYMERS FOR ENERGY CONVERSION AND STORAGE 9

Basic of electrochemical energy devices; organic/plastic/flexible solar cells, polymer composites for solar cells, device fabrication and characterization; mechanism and materials for different types of batteries, super capacitor; fuel cells- polymer membranes for fuel cells.

UNIT IV POLYMERS IN LITHOGRAPHY AND WATER TREATMENT 9

Polymers in lithography - photo resist - positive resists - negative resists - solution inhibition resists image reversal process - polymer membrane –polymer complexes for water treatment.

UNIT V POLYMERS FOR BIOMEDICAL APPLICATIONS 9

Polymer for biomedical applications - polymers in dentistry – tissue adhesives - dialysis membrane - blood oxygenators - bone cement - prostheses - biodegradable sutures - control drug delivery systems.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Discuss about the various types of engineering plastics.
CO2: Analyze and choose polymers for high temperature applications.
CO3: Evaluate the use of polymers in energy storage devices.
CO4: Assess polymers for lithography and water treatment applications.
CO5: Analyze and choose polymers for bio-medical applications.

REFERENCE BOOKS:

1. H.F. Mark , “Encyclopedia of Polymer Science and Engineering”, Wiley – Interscience, NewYork, 3rd edition, 1991.
2. L.L. Chapoy, “Recent Advances in Liquid Crystalline Polymers”, Chapman and Hall, London, 1985.
3. R.W. Dyson, “Specialty Polymers”, Springer netherland, 1998.
4. C.P.Wong, “Polymers for Electronic and Photonic Applications”, Academic Press, NewYork, 2013.
5. Manas Chanda, Salil K. Roy, “Industrial Polymers, Specialty Polymers, and their Applications”, CRC Press, 2008.
6. Robert William Dyson, “Specialty Polymers”, 2nd edition, Springer Verlag,2011.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	3	2	1

CO2	3	2	2	3	2	1
CO3	3	2	2	3	3	1
CO4	3	2	2	3	3	1
CO5	3	2	2	3	2	1
Average PO	3	2	2	3	2.4	1

PL3009 PLASTICS MOULD MANUFACTURING TECHNOLOGY L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Demonstrate the mould manufacturing process.
- Select mould materials, metal cutting tools, CNC.
- Analyze of mold assembly, product dimension and precision.
- Inspect the structure and functions of the mould.

UNIT I MATERIALS 9

Mould materials for mould making and for various mould elements - ferrous, non ferrous, steel, aluminum, copper, magnesium alloys, bronze - miscellaneous materials - alloying elements - factors considered for selection of material in mould making - standards for mould materials - heat treatment for mould materials - annealing, hardening, quenching, nitriding, carburizing, carbonitriding, tempering - advance heat treatment formould materials - IS standards, British standards for mould materials.

UNIT II TOOLING 9

Metal cutting tools - tool angle - single and multipoint cutting tool - cutting fluids - mechanism of metal cutting - tool materials - coated tool materials - machining operations – conventional tooling machines- shaper, planner, - lathe - turning, drilling, milling - horizontal, vertical, universal type – jig boring - grinding - hobbing – engraving - pantograph.

UNIT III CNC & RAPID TOOLING 9

Introduction of NC and CNC -programming - G and M codes - CNC machines - CNC EDM (wire EDM), CNC Milling, CNC Lathe- CNC machining and turning center - rapid vs

conventional tooling - mould element development using rapid tooling- application of rapid tooling.

UNIT IV MOULD FINISHING AND ASSEMBLY 9

Definition of surface roughness - Polishing of mould - polishing tools & types – Methods of polishing - electrosonic polishing – ultrasonic polishing – Principles of Electro deposition in damaged moulding surfaces/Protective Coating - surface texturing of moulds - photochemical etching - nickel and chromium plating – chemical texturing – Mould assembly - fitting and assembly of mould elements - check list for mould assembly - mould trial &maintenance.

UNIT V INSPECTION 9

Dimension and tolerance - accuracy and precision - working principle and application of measuring instruments used in tool room – coordinate measuring machine (CMM) - micrometer, surface plates, angle plates, squares, vernier height gauges, depth gauges, slip gauges, dial gauges, surface roughness measurement – hardness testing comparators - optical profiles projectors, tool makers microscope –optical flats.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Select the material for mould depending upon application and processing

CO2:. Demonstrate the mould manufacturing techniques.

CO3: Formulate metal cutting tools, CNC based tool room machineries and its application in

mould manufacture.

CO4: Construct the concepts of mould maintenance

CO5: Analyze the different inspection techniques

REFERENCE BOOKS:

1. Klus Stokhert (Edt.), "Mold making handbook for Plastic Engineers", Hanser Publishers, NY,2nd edition1998.
2. HMT "Production Technology", *Tata McGraw-Hill*(India),1998.
3. Sanjay K. Nayak, "Plastics Mould Technology", Vol -1 and 2, CIPET Publications,2007.
4. P.C.Pandey & H. S. Shah, "Modern Machining" Processes, TMH,1981.
5. Jain R K, "Engineering Metrology", 19th Edition, Khanna Publishers,2005.
6. Peter Jones, "The Mould Design Guide", Smithers Rapra Technology Ltd.,2008.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	3	3	2	-	3
CO2	-	3	3	2	-	-
CO3	1	3	3	2	-	-
CO4	1	3	3	2	-	3
CO5	-	3	3	2	-	3
Average PO	1	3	3	2	-	3

PL3010 POLYMER BLENDS L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Compare and contrast the polymeric blends and alloys.
- Differentiate compatibilizer and high performance blends
- Prepare and analyze the polymer blend and its rheology.
- Analyze and evaluate the characterization of polymer blends.

UNIT I POLYMER BLENDS 9

Polymer blends and alloys - Need for making polymer blend - selection criteria - classification of polymer blends- mechanism of mixing and dispersion - extensive, intensive mixing, solid-solid, solid- liquid, liquid- liquid - thermodynamic law of miscibility - Mixing theories- Flory Huggins, Gaslattice model - principle of phase equilibria calculations -mechanism of phase separation , Advantages of blending.

UNIT II COMPATABILIZATION OF POLYMERS 9

Reactive Compatabilization - methods and mechanism of compatibilization- block and graft copolymers as compatabilizers – block co Compatabilization by reactive blending - Crystallization of polymer blend -Interpretation of polymer/polymer interactions.

UNIT III PREPARATION TECHNIQUES AND RHEOLOGY OF POLYMER BLENDS 9

Blend preparation techniques, Solution blending, Latex blending, Melt blending, Mechanical mixing, mechano-chemical mixing, In situ polymerization – Flow behavior of polymer blends – flow behavior of miscible and immiscible polymer blends – complex flow - visco-elastic response of polymer blends. Microstructure and blend performance.

UNIT IV LCP POLYMER BLENDS 9

High performance polymer blends- LCP blends – LCP/Polyester blends, LCP/Polyolefin blends, LCP/Polyethersulfone blend, LCP/thermoplastic polyimide blend, LCP/LCP blends.

UNIT V CHARACTERIZATION OF POLYMER BLENDS 9

Fourier transformed Infrared Spectroscopy (FTIR) – X-Ray Diffraction (XRD), Microscopic Techniques - Optical microscopy - Electron Microscopy: scanning electron microscopy -

Transmission electron microscopy, Thermal analysis Differential scanning calorimeter, Glass transition temperature, Light scattering - X Ray Scattering Technique.

TOTAL: 45 PERIODS

OUTCOMES:

At the end of the course, students will be able to

CO1: Demonstrate on miscibility behavior based on thermodynamics
CO2: Experiment solubility parameter and compatibility of blends.
CO3: Compare the techniques involved in polymer blend preparation.
CO4: Prepare blends of various polymers for different applications
CO5: Compare various spectroscopic characterization techniques of polymer blends

REFERENCE BOOKS:

1. D.R. Paul, "Polymer Blends", volume 2, John Wiley & sons, edition,2000
2. L.A.Utracki, "Commercial Polymer Blends", Chapman & Hall, London,1998.
3. RP. Singh, C.K. Das, S.K. Mustafi, "Polymer Blends and Alloys an overview", Asian Books Pvt. Ltd.,1st edition, New Delhi-2002.
4. Murali srinivasan Natamai Subramanian, "Polymer Blends and Composites - Chemistry and Technology", Scrivener Publishing LLC,2017.
5. Gabriel O. Shonaike, George P. Simon, "Polymer Blends and Alloys", CRC Press.1999.
6. Lloyd M. Robeson, "Polymer Blends: A Comprehensive Review", Hanser, 2007

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	1	1	1
CO2	3	2	3	1	1	1
CO3	3	2	3	-	1	1
CO4	3	2	3	-	-	1
CO5	3	2	3	1	-	1
Average PO	3	2	3	1	1	1

PL3011 POLYMER NANOCOMPOSITES L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Select of nano-composites for various applications.
- Evaluate the structure and properties of nanostructured polymer composites.
- Analyze the components and preparation of bio based nanocomposites.
- Compare the rheological and thermal properties of nano-composites.
- Appreciate the applications of nanocomposites in automotive and health care.

UNIT I NANOCOMPOSITES - AN INTRODUCTION 9

Introduction - Organic and Inorganic materials - Polymer Nanocomposite Materials; Preparation of nanostructured materials - top-down processes, bottom- up processes, template assisted structuring of nanomaterials, ordering of nanostructures; Nanoscale fillers – Clay, POSS, CNT, nanoparticle fillers. Nano ceramic for Ultra high temperature MEMS; Optimizing nano filler performance in polymers; Preparation techniques; Modification of interfaces; Macromolecules at interface and structured organic films; Processing into nanocomposites.

UNIT II NANOSTRUCTURED POLYMER COMPOSITES 9

Nanocomposites: particulate, clay, and carbon nanotube, graphene nanocomposites. synthesis, characterization, properties, and applications. Flow behavior of carbon nanofiber- based polymeric nanocomposites; Rheology in polymer/clay nanocomposites: mesoscale structure development and soft glassy dynamics; Polymer- graphite nanocomposites; Polymer nanocomposite-

flammability and flame retardancy.

UNIT III BIO NANOCOMPOSITES 9

Methods of preparation of bio nano composites – components - Animal based fiber reinforced composites; Biopolymeric nanofibers for tissue engineering; Potential use of poly hydroxyl alkanotes for tissue engineering; A reductionist approach for the molecular and supramolecular structures of elastin; Elastic based polymer nanocomposites; PLA based bio and nanocomposites; Toxicology of bio - nano composites – Applications of bio nanocomposites.

UNIT IV SHEAR RHEOLOGY OF NANOFIBER BASED COMPOSITES 9

Introduction; Rheology background; Preparation of suspensions and composites; Rheological characterization- Start-up of steady shear, steady state shear measurements, small amplitude oscillatory shear measurements, measurements of temperature effects; Modeling of CNF suspensions; Modeling of CNF/ PS melt composites- Modeling and simulation methods.

UNIT V APPLICATIONS OF NANOCOMPOSITES 9

Barrier and membrane applications; Composite products based out of flammability resistance; Polymer blend compatibilization; Biomedical applications, Fuel cell applications, Electrical/ electronic applications; Optoelectronics, Sensors; Automotive applications; Tyres; Wound care; Sport goods; Personal protective equipments.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Demonstrate the preparation of nanomaterials.
CO2: Analyse the science of nanomaterials
CO3: Evaluate the properties of polymeric bio nanocomposites.
CO4: Correlate the shear rheology of nanofiber based composites.
CO5: Apply polymer nanocomposites in various fields.

REFERENCE BOOKS:

1. Polymer Nanocomposites: Processing, Characterization, and Applications, 2nd Edition Joseph H. Koo, Sc.D 2019 McGraw-HillEducation.
2. Kelsall, R., Hamley, I. W.,&Geoghegan, M. , “Nanoscale science and technology”.John Wiley & Sons,2005.
3. Advani, S. G., “Processing and properties of nanocomposites”, WorldScientificPub..,2007.
4. Pradeep, T,“Nano The essentials Understanding Nanoscience and Nanotechnology”.2008.
5. Lau, A. K. T., Hussain, F., & Lafdi, K., “Nano-and biocomposites”. CRC Press,2009.
6. Peters, S. T, “Handbook of composites”. Springer Science & Business Media,2013.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	2	1	2	3	2
CO2	3	2	1	2	3	2
CO3	3	2	1	2	3	2
CO4	3	2	-	2	3	2
CO5	3	2	-	2	3	2
Average PO	3	2	1	2	3	2

PL3012 POLYMER REACTION ENGINEERING L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Discuss reaction kinetics and evaluation of reaction rate.
- Evaluate reactor design and to know about the effect of mixing on kinetics and MWD.
- Distinguish the mechanisms of various polymerizations.
- Interpret various polymerization techniques.
- Construct safety aspects and green approach in polymerization reactions.

UNIT I KINETICS OF POLYMERISATION 9

Introduction to reaction kinetics - rate equation Polymerization kinetics for step growth and chain growth Bonding forces in polymers – Control on polymer synthesis - Interpretation of Batch Reactor data for irreversible reactions taking place in constant volume and variable pressure batch reactors – differential, integral, initial rate, half life, Graphical methods of Analysis and method of excess.

UNIT II INTRODUCTION TO REACTOR DESIGN 9

Control of molecular weight and molecular distribution - the effect of mixing on kinetics and MWD - Different types of blenders - Micro structural features of polymers and their effect on properties - Chain branching, cross linking Units and dimensions, material balance, energy balance. Polymerization reactor design: batch reactors, plug flow reactors, continuous stirred tank reactors - Prediction of molecular weight distribution in different reactors, heat transfer problem in polymer manufacture.

UNIT III POLYMERIZATION MECHANISMS 9

Radical Chain growth polymerization – Radical chain polymerization in comparison with ionic chain polymerization – mode of propagation – rate of polymerization – process analysis – Half-life, Propagation & termination – Redox initiators, photochemical and ionization initiators - Step-growth polymerization – Molecular weight distribution – Linear step growth polymerisation - Copolymerization – Coordination polymerization – Zeigler Natta Catalyst – Mechanism - Stereo specific polymers

UNIT IV TEQUNIQUES OF POLYMERIZATION 9

Polymerization techniques - Homogeneous polymerization, Quiescent and stirred bulk polymerization – solution polymerization - advantages and disadvantages - Heterogeneous polymerization. Smith-Ewart Model, Emulsion polymerization, Inverse emulsion polymerization, Mini-emulsion polymerization, Micro-emulsion polymerization, Dispersion polymerization.

UNIT V REACTION PROCESSES AND SAFETY 9

Polymerization process control - cleaning, maintenance of reactors and pipelines principle of chemical reactor safety applied to polymerization reactors – Principles of Green synthesis & Green Engineering – Safer technology steps – Inherently safer process and equipment design – Guide for risk assessment – control system design – Case studies on Industrial accidents.

TOTAL: 45 PERIODS

COURS OUTCOMES:

At the end of the course, students will be able to

CO1: Discuss the reaction kinetics and evaluation of reaction rate.
CO2: Design stirrers and to know about the effect of mixing on kinetics and MWD.
CO3: Distinguish mechanism of polymerization.
CO4: Evaluate various techniques of polymerization processes
CO5: Create safer reactor design and greener approach in polymerisation.

REFERENCE BOOKS:

1. Octave Levenspiel, “Chemical Reaction Engineering”, 3rd edition, John Wiley & Sons,1998.
2. AsuaJ. M., Polymer Reaction Engineering, Edited by Blackwell Publishing,2008.
3. Gupta S. K. and Anil kumar,” Reaction Engineering of Step Growth Polymerization”,

Plenum Press, New York1987.
4. McGreavy, "Polymer Reactor Engineering" Blackie Academic & Professional, Chapman & Hall,1994
5. Dr.Thierry Meyer and Prof. J. Keurentjes "Handbook of Polymer Reaction Engineering", Wiley-VCH Verlag GmbH & Co. KGaA, 2005.
6. J.A. Biesenberger and D.H. Sebestian, "Principles of Polymerization Engineering",Wiley,1983.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	0	2	1	0
CO2	2	0	0	2	3	3
CO3	0	0	1	2	1	1
CO4	3	2	3	0	2	3
CO5	0	0	3	3	2	2
Average PO	**2.3**	**2**	**2.3**	**2.3**	**1.8**	**2.3**

PL3013 PLASTIC WASTE MANAGEMENT L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Compare the plastic waste types and policies on plastic waste management.
- Distinguish the primary and secondary recycling techniques and their limitations.
- Select the tertiary or quaternary recycling recycling of plastics.
- Value the challenges faced in plastic recycling.
- Construct new efficient recycling techniques for recent category of waste.

UNIT I PLASTIC WASTES 9

Sources of plastics waste – Types of plastic waste – Industrial plastic waste - generation of industrial plastic waste – waste generation factor – statistical analysis - plastic in solid waste; Separation of components in municipal refuse – Global statistics - Global and Indian data -- Plastic waste management rules and regulations – plastic Bans – China sword policy impacts – Impact on global plastic waste management.

UNIT II PRIMARY ANDSECONDARY RECYCLING 9

Primary recycling – degradation of plastics – Problems associated with primary recycling; Secondary recycling – approaches to secondary recycling – mechanical reworking of plastic waste – chemical modification of mixed plastic waste – co- extrusion and co-injection moulding – waste plastics as fillers.

UNIT III TERTIARY AND QUATERNARY RECYCLING 9

Tertiary recycling – chemicals from plastics waste – pyrolysis and chemical decomposition of plastic waste – Chemolysis – Thermolysis (Pyrolysis, Gasification and Hydrogenation) – depolymerisation - Quaternary recycling energy from plastics waste – incinerator – Use of plastics on road construction.

UNIT IV CHALLENGES IN PLASTICS RECYCLING 9

Recycling of plastics – surface refurbishing; Plastics aging – environmental aging – thermal aging – weathering – chemical degradation – ionizing radiation – wear and erosion; Biodegradation – biodegradable plastics – photodegradable plastics. Impact of plastic pollution on marine life, Health and Environmental impact. Possible greener alternatives for plastics – Plastics resource recovery and circular economy – case studies. Microplastics – causes and effects.

UNIT V CIRCULAR ECONOMY AND BUSINESS OPPORTUNITIES 9

A differential - Linear Vs Circular Economy; Circular economy - Material recovery, Waste Reduction, reducing negative externalities, Explaining Butterfly diagram, Concept of Loops; Zero waste: Waste Management in context of Circular Economy, Circular design, Research and innovation, LCA, Circular Business Models; Plastics: A case study, EPR: polluters pay principle, Industrial symbiosis/ Eco-parks; Role of governments and networks, Sharing best practices.

TOTAL:45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Compare plastic waste types and policies on plastic waste management.
CO2: Distinguish primary and secondary recycling techniques and their limitations.
CO3: Develop techniques for recycling plastics into economically useful products.
CO4: Analyze the challenges in plastic recycling.
CO5: Evaluate business opportunities in plastic waste using circular economy.

REFERENCE BOOKS:

1. Plastic Waste and Recycling: Environmental Impact, SocietalIssues, Prevention, and Solutions, Trevor Letcher, Academic Press,2020.
2. Towards Zero Waste: Circular Economy Boost, Waste to Resources María- Laura Franco-García, Jorge Carlos Carpio-Aguilar, Hans Bressers.Springer International Publishing2019.
3. The Circular Economy: A User's Guide Stahel, Walter R. Routledge2019
4. Nabil Mustafa, "Plastics Waste Management: Disposal, Recyling and Reuse",Marcel Dekker Inc., New York,1993.
5. R. J. Ehrig, "Plastic recycling: Products and Processes", Hanser Publishers, NewYork,1992.
6. Jacob Leidner, "Plastic waste: Recovery of Economic Value", Marcel Dekker Inc.,New York,1982.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	-	-	2	3
CO2	2	1	-	1	2	3
CO3	2	1	1	1	2	3
CO4	2	-	1	1	2	3
CO5	2	-	1	-	2	3
Average PO	2	1	1	1	2	3

PL3014 POLYMERS FOR BIOMEDICAL ENGINEERING APPLICATIONS L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Analyse the types of biopolymers and their advantages and needs.
- Compare various types of bio-materials and their applications for bio-medical engineering.
- Analyse various bio-materials used in processing of components and the basic destructive and non-destructive testing of such biomaterials.
- Organize fabrication of bio-composites in biomedical applications.
- Create biocompatible biomedical devices using suitable biopolymers.
- Evaluate the modification techniques conventionally used for biomedical devices.

UNIT I BIOMATERIALS IN MEDICINE 9

Introduction to classes of materials used in medicine, world-wide market for biomaterials, clinical

implications of biomaterials development. Types of materials - inert, toxic, bioactive, natural materials - collagen, biopolymers etc. Introduction to biocompatibility, requirements and standards, cell- material interaction, testing of biomaterials, in vitro assessment, invivo assessment of tissue compatibility, testing of blood-materials interaction, animal models.

UNIT II BIO POLYMERS 9

Polymers as biomaterials, silicones, polyurethanes, polyvinyl chloride, Ultrahigh molecular weight polyethylene, polyacrylates, polyether ether ketone, water soluble polymers, hydrogels, bio- adhesives, diffusion principles, polymers for controlled drug delivery applications, polysaccharides, poly(orthoesters), polyanhydrides, aminoacid derived polymers, polyphosphazenes, bacterial polyesters.

UNIT III COMPOSITES IN BIOMEDICAL APPLICATIONS 9

Concepts of polymer composites, composites - reinforcing systems-fabrication, mechanical properties, dental filling composites, fibrous and particulate composites in orthopedic implants. Biomimetic materials, nanoscale materials/engineering; bioactive/bioresponsive materials, polymer scaffolds, principles of tissue engineering.

UNIT IV MEDICAL DEVICES 9

Medical devices, medical device development, material choice, device design, extracorporeal devices, oxygenators, intravenous catheters, stents, polymeric implants, heart valves, total artificial heart, cardiac pace makers, vascular grafts, artificial kidney, dialysis membranes, hard tissue implants, orthopedic implants, fracture plates, intramedullary devices, spinal fixation, joint replacements, bone cement, soft tissue replacements, wound dressing, artificial skin, sutures, contact lenses, tissue adhesives, maxillofacial implants, ear and eye implants, controlled drug delivery systems, biosensors, gloves, condoms, urinary catheters, intrauterine systems, cosmetic implants. Regulation and standards for quality, FDA, EU-medical directives, GMP, GLP, ISO, CE marking etc.

UNIT V MODIFICATION TECHNIQUES 9

Surface modification techniques, plasma modifications, coating methods. Sterilization methods, dry heat, steam, ethylene oxide, gamma ray, effect of sterilization on polymers, importance of packaging, shelf-life.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Analyze the use of biomaterials in medical field
CO2: Demonstrate preparation and properties of bio-polymers
CO3: Apply bio-polymeric materials for making components in various fields.
CO4: Analyze different medical devices and its functions.
CO5: Apply suitable modification techniques

REFERENCE BOOKS:

1. Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen and Jack E. Lemons, “BiomaterialScience: An Introduction To Materials In Medicine”,(2012)
2. Shishir Sinha| Naveen Kumar Navani| Ex. Ed. J.N. Govil Nanotechnology “Biomaterials”, Vol. 11(2014).
3. Sabu Thomas, Dominique Durand, Christophe Chassenieux, P. Jyotishkumar, “Handbook of bio-polymer based materials, Technology & Engineering” (2013), John Wiley &Sons.
4. Plackett, D., “Biopolymers: New Materials for sustainable films & Coatings”, John Wiley & Sons,2011.
5. D.L. Wise et al. Eds., “Encyclopedic handbook of Biomaterials and Bioengineering, Part A. Materials & part B. Applications”, Volume 1 &2, Marcel Dekker Inc, BPS2305
6. John Enderle and Joseph Bronzino, Introduction to Biomedical Engineering, 3rd Edition, Academic press, Elsevier,2012.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	3	-	3
CO2	2	1	2	3	-	3
CO3	2	1	2	3	1	3
CO4	2	-	2	3	1	3
CO5	2	-	2	3	1	3
Average PO	2	1	2	3	1	3

PL3015 POLYMERS FOR PACKAGING APPLICATIONS L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Select on polymers as packaging material
- Distinguish flexible packaging materials
- Implement the rigid packaging materials and to analyze the molding techniques
- Analyze various food packaging materials and their problems
- Design testing for packaging materials

UNIT I POLYMERS FOR PACKAGING 9

Polyethylene (LDPE, HDPE, LLDPE), Polypropylene, Polyvinylchloride, Polyvinylidene chloride polycarbonate, polystyrene, polyvinyl alcohol, nylon, polyester, polycarbonate, fluoro polymers, ABS, and poly acrylonitrile.

UNIT II FLEXIBLE PACKAGING MATERIALS 9

Sheet and film, Extrusion and Extruders – cast and blown films, stretch and shrink wrap, film and sheet Co-extrusion, laminated film, metallized film, Smart films, microwavable films, edible and soluble films. Types of flexible packaging – bags, pouches, collapsible tubes, bag-in-box, flexible cans and sacks.

UNIT III RIGID PACKAGING MATERIALS 9

Material selection for rigid packaging, additives and compounding, Injection molding - closures, rotational molding, compression molding, blow molding-extrusion, injection, stretch, and aseptic blow molding – Plastic bottles, tubes, plastic pallets, drums, barrels, Jerry cans and shipping containers, Types of thermoforming – Drape, Vacuum and pressure forming

UNIT IV POLYMERS FOR FOOD PACKAGING 9

Properties of polymers for packaging, interaction between products and packaging. Biobased and biodegradable material for packaging - ecofriendly natural fibers for packaging-bio nanocomposites and their potential application in packaging industries

UNIT V TESTING OF PACKAGING MATERIALS 9

Packaging testing – Mechanical properties – tensile tear and impact properties, burst strength, stiffness, crease and flex resistance. Optical properties – clarity, haze and gloss. Barrier properties – oxygen transmission, water vapor transmission rate migration. Chemical resistance tests

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Select various polymers used for packaging applications
CO2: Distinguish flexible polymeric packaging materials and their types
CO3: Implement rigid polymers as packaging materials
CO4: Analyze food packaging materials and their issues

CO5: Design tests for polymeric packaging materials.

REFERENCE BOOKS:

1. Gordon.L Robertson, “Food Packaging”, Taylor and Francis(2006)
2. Sajid Alavi, Sabu Thomas, K. P. Sandeep, Nandakumar Kalarikkal, Jini Varghese, Srinivasarao Yaragalla, “Polymers for Packaging Applications”, Apple Academic Press, 2014
3. John R. Wagner, Jr., Crescent Associates, Inc., Rochester, “Multilayer Flexible Packaging”, lsevier2009
4. S.Ebnesajiod, W.Andrew, “Plastic films in food packaging”, PDL,2012.
5. Manas Chanda, Salil K.Roy,“Plastics Technology Hand book”, 2nd edition, MarcelDekker,NewYork,1993.
6. H.F.Mark,(Ed), “Encyclopedia of Polymer Science & Engineering”. John Wiledy & Sons,New York,1989.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	1	-	2
CO2	2	1	3	1	-	2
CO3	2	-	3	1	1	2
CO4	2	-	3	-	1	2
CO5	2	1	3	-	1	2
Average PO	2	1	3	1	1	2

PL3016 RUBBER TECHNOLOGY L T P C
3 0 0 3

OBJECTIVES:

To prepare the students to

- Interpret Rubber and Specialty Rubbers.
- Construct vulcanization processing and compounding of rubber.
- Develop and design sealing applications and tyres.
- Value on quality control and testing methods of rubbersused.

UNIT I FUNDAMENTALS OF RUBBER 9

Rubber Elasticity: Basic Concepts and Behavior, Elasticity of a Single Molecule, Elasticity of a three - Dimensional Network of Polymer Molecules, Selection Criteria for a polymer to behave as a rubber, polymerization types and. Ozone attack on rubbers– protection against oxidation. Vulcanization – mechanism of sulphur cure - effect of crosslink density on properties – role of accelerators, activators – non–sulphur vulcanization systems.

UNIT II SPECIALTY RUBBERS 9

Heat resistant rubbers – polyisobutylene, butyl and EPDM rubbers – solvent/oil resistant rubbers– nitrile, neoprene and chloroprene rubbers, EMA,ACM,EVA – hypalon and chlorinated PE – high performance, specialty and modified rubbers – fluorine containing and silicone rubbers, polyurethanes , polyethers & polysulphide.

UNIT III PROCESSING AND COMPOUNDING OF RUBBER 9

Common ingredients for formulation of a rubber compound. Rubber processing – mixing operations – composition, concentration, stabilization, coagulation, open mill mixing, internal and continuous mixers – forming operations – calendaring –extrusion–spreading and moulding operations. Need for compounding-two roll mill- internal mixer–machine design and mix quality. Compound design- UV stability, Chemical stability, Oil resistance.

UNIT IV RUBBERS IN SEALING APPLICATIONS AND TYRES 9

Types of Seals - Gaskets - Flexible couplings Design considerations – Conveyer Belts V-belts. Troughing moulded, braided and hand–built hoses. Tyres – functions, requirements – basic

design reinforcing systems. Block copolymers for dynamic applications including Tyres, Naval and space applications of rubber, Green tyre technology, Intelligent tyres - new generation tyres. Sustainable recycling technologies - Tyre recycling - Applications of recycled rubber.

UNIT V QUALITY CONTROL, TESTING OF RUBBERS 9

Tyre Mechanics – Forces acting on Tyres – Steering properties - slip angle, Aligning Torque, tyre noise, Tread Wear, SPC charting, rheograph data, DOE, Taguchi method. Hardness (Shore A and IRHD),Compression Set, Load deflection, Rheology (MDR), TGA, Tensile stress-strain, Peel, Fluid Swell, Vibration analysis, Thermal Conductivity and Radiation Resistance. Tyre Testing – Destructive and Non-destructive Testing of Tyres, Tyre Labelling.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Recognize and list out the preparation and properties of rubbers.
CO2: Discuss the properties of Specialty rubbers.
CO3: Develop capacity to appreciate and demonstrate compounding of rubbers.
CO4: Analyze and organize the applications of rubbers.
CO5: Judge the current trends in testing of rubber processing technology.

REFERENCE BOOKS:

1. M.Morton, Rubber Technology, Van Nostrand Reinhold, 1987.
2. A.K. Bhowmick and H.L.Stephens, Hand Book of Elastomers, Marcel Dekker, New York,1988.
3. J. A. Brydson, Plastic Materials, Elsevier Publishers Group, 2014.
4. 4.C. M.Blow and C.Hepburn, “Rubber Technology and Manufacture”, 2rdEdn., Butterworths, London, 1982.
5. B. Kothandaraman, Rubber Materials, Ane Books Pvt. Ltd., New Delhi, 2008.
6. J.M. Martin, W.K.Smith, Handbook of Rubber Technology, Vol. 1 & 2, CBS Publishers & Distributors,2004.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	2	3
CO2	3	2	3	2	2	3
CO3	3	2	3	2	2	3
CO4	3	2	3	2	2	3
CO5	3	2	3	2	2	3
Average PO	3	2	3	2	2	3

PL3017 SPECIALTY POLYMERS L T P C
3 0 0 3

OBJECTIVES

To prepare the students to

- Interpret the liquid crystalline polymers.
- Distinguish conducting and piezoelectric polymers.
- Develop heat resistant polymers.
- Construct photosensitive polymers and coating additives.
- Apply polymers for specialty applications.

UNIT I LIQUID CRYSTALLINE POLYMERS (LCPS) 9

Concept of liquid crystalline (LC) phase, definition and synthesis, liquid crystalline polymers - types and their classification - theories of liquid crystallinity, characteristics of LC state and LCPs,

liquid crystalline elastomers, structure property relationship, rheology of liquid crystalline polymers, biphasic behaviour, blends of LCPs, self-reinforced composites, applications of LCPs.

UNIT II CONDUCTING POLYMERS 9

Theory of conduction, semi-conductors and conducting polymers, Background of conducting polymers, conductivity range of commercial polymers, band theory, requirements for polymer to work as conductor, types of conducting polymers - intrinsic and extrinsic, doping of polymeric systems, self-doped polymers, Mechanism of conducting polymers- Polyaniline, Polyacetylene, Polypyrole, polythiophene, polyphenylene sulphide, organo-metallic polymers – Photo conducting polymers- Polymers with Piezzo, ferro and pyro electric properties.

UNIT III HEAT RESISTANT POLYMERS 9

Requirements for heat resistance, determination of heat resistance, synthesis, structure-property relationships, methods to improve thermal stability and fire resistance, applications of heat resistant polymers like polyamides, polyimides and its derivatives, polyquinolines, polyquinoxalines, Polymers for high temperature resistant applications, - PBT, PBO, PBI, PPS, PPO, PEEK, Fluro polymers, aromatic polymers and heterocyclic polymers.

UNIT IV PHOTOSENSITIVE POLYMERS AND POLYMERS AS COATING ADDITIVES 9

Photosensitive polymers - synthesis, curing reactions, applications in various fields. Photo resists for semiconductor fabrication, photoresists applications for printing, Membranes, their types, methods of casting and their applications. Polymer as coating additives - types, synthesis, requirements for polymer to work as coating additives and applications.

UNIT V POLYMERS IN MISCELLANEOUS SPECIALTY APPLICATIONS 9

Polymers in agricultural applications: green houses, mulches, control release of agricultural chemicals, seed coatings, etc., polymers in construction and building applications, polymer concrete– applications, Shape memory polymer, polymeric materials used in telecommunication, optical fiber telecommunication cables and power transmission applications, polymer composites in aerospace and other light weight applications, polymers for biomedical application, polymers in cosmetics.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Assess the concept of liquid crystalline polymers.
CO2: Value the importance of doping in polymeric systems.
CO3: Apply the polymers for high temperature applications.
CO4: Identify the application of photo resists and polymeric coatings.
CO5: Evaluate the polymers for agricultural, aerospace and telecommunication fields

REFERENCE BOOKS:

1. Manas Chanda, Salil K. Roy, Industrial Polymers, Specialty Polymers, and their Applications, CRC Press,(2019).
2. Faiz Mohammad, Specialty Polymers: Materials and Applications, I.K. International Pvt Ltd, (2013).
3. Matrin. T. Goosey," Plastics for Electronics", Elsevier, Applied Science,(2012).
4. Robert William Dyson, Speciality Polymers, Blackie Academic & Professional, 2nd Edition, (2011).
5. Manas Chanda, Salil K. Roy," Plastics Technology Hand book ", 4th edition, CRC Press, Taylor & Francis Group,2007.
6. Johannes Karl Fink, Hand book of Engineering and Specialty Thermoplastics, Vol 2, Wiley-Scrivener, 1st Edition (2011).

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	1	2	1
CO2	2	2	2	1	2	1
CO3	2	2	2	1	2	1
CO4	2	2	2	-	2	-
CO5	2	2	2	-	2	-
Average PO	2	2	2	1	2	1

PL3018 SYNTHETIC RESINS L T P C
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OBJECTIVES:

To prepare the students to

- Differentiate the natural and synthetic polymers and its commercial applications.
- Value the water soluble polymers and its applications in various fields.
- Compare and contrast the thermoplastics and thermosetting resins and their engineering applications.
- Construct varieties of synthetic rubbers and fibers.

UNIT I CLASSIFICATION OF POLYMERS 9

Introduction – Classification of natural, modified and synthetic polymers – effect of structure on properties of polymers — Salient features of plastics-water soluble polymers – classification functions and properties – starch - dextrinization – modified starches – cellulose and its derivatives- commercial Applications.

UNIT II WATER SOLUBLE POLYMERS 9

Synthetic water soluble polymers, preparation, properties and applications of polyvinyl alcohol – polyvinylpyrrolidone – polyacrylic acid and its homolog's – polyacrylamide – polyethylene oxide – polyethylene mine. Application of water soluble polymers in pharmaceuticals – cosmetics –textiles – paper – detergents and soaps – paint –flocculation – beverages – polyelectrolyte's.

UNIT III THERMOPLASTIC RESINS 9

Thermoplastic resins – polyolefins – vinyl polymers – poly vinyl chloride-polystyrene – PMMA – SAN – PAN - Teflon – polyamides – polycarbonates and theirapplications.

UNIT IV THERMOSETTING RESINS 9

Thermosetting resins – phenolic resins – aminoplast – UF- MF - polyesters – alkyd resins– epoxies – bisphenol - A and cycloaliphatic based epoxy resins -polyurethanes and polyureas – silicone resins.

UNIT V RUBBERS AND FIBERS 9

Elastomers – natural rubber – vulcanization - synthetic rubbers – butyl - SBR neoprene. Application of synthetic resins as fiber – commodity plastics – sheets and film – foam – packaging – biodegradable and engineering applications.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

At the end of the course, students will be able to

CO1: Differentiate the natural and synthetic polymers and its commercial applications.
CO2: Develop and appreciate the applications of water soluble polymers.
CO3: Compare and contrast the properties of thermoplastic resin and their trade names.

CO4: Analyze the preparation of various thermosetting resins.
CO5: Construct various rubbers and its formulations.

REFERENCE BOOKS:

1. J.A. Brydson, “Plastics Materials”, Newness - Elsevier, Seventh Edn, London, 2014.
2. R.L. Davidson and S. Marshall, “Water Soluble Resins”, Van-Nostrand Reinhold, NewYork, 1988.
3. R.B. Seymour and C.E.Carraher, Jr., “Polymer Chemistry – An Introduction”, Marcel Dekker Inc., New york, 2010.
4. Maurice Morton, “Rubber Technology”, Van Nostrand Reinhold, New York, 2002.
5. Qipeng Guo, "Thermosets, Structure, Properties, and Applications",2nd Edition, Elsevier November 2017.

COURSE ARTICULATION MATRIX

Course Outcome	PO					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	1	-	1	-	1
CO2	3	1	-	-	-	1
CO3	3	1	-	-	1	1
CO4	3	-	-	1	1	-
CO5	3	-	-	1	1	-
Average PO	3	1	-	1	1	1