KAMARAJ
COLLEGE OF ENGINEERING & TECHNOLOGY

(An Autonomous Institution - AFFILIATED TO ANNA UNIVERSITY, CHENNAI)
S.P.G.Chidambara Nadar - C.Nagammal Campus
S.P.G.C.Nagar, K.Vellakulam - 625 701, (Near Virudhunagar), Madurai District.

DEPARTMENT OF POLYMER TECHNOLOGY
M.Tech. POLYMER SCIENCE AND ENGINEERING
REGULATIONS –2020 - AUTONOMOUS
CHOICE BASED CREDIT SYSTEM
I TO IV SEMESTERS CURRICULUM AND SYLLABUS

Vision of the Department:

- To make the Department of Polymer Technology of this Institution the unique of its kind in the field of Research and Development activities in this part of the world.

Mission of the Department:

- To impart highly innovative and technical knowledge in the field of Polymer Technology to the urban and unreachable rural student folks through Total Quality Education.

Program Educational Objectives (PEOs):

- **PEO 1**: Graduates will be technically proficient in Polymer Science & Engineering and acquire up-to-date knowledge for professional success.
- **PEO 2**: Graduates will exhibit a professional work ethic including an interest in personal and Professional growth.
- **PEO 3**: Graduates will be aware of how their professional role will impact the global Community.

Program Specific Outcomes (PSOs):

- **PSO1. Research:** To apply basic principles of polymer science and engineering in various interdisciplinary fields to engage various levels of research activity.
- **PSO2. Placement and Entrepreneur:** Learn future technologies through acquired foundation skills and knowledge and employ them in industry and business environments

The credit requirement for the programme M.Tech. Polymer Science and Engineering (as per Regulation 2020) is outlined below:

SEMESTER-I

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
		THEORY						
1	PE1101	Elastomer Technology	PC	3	3	0	0	3
2	PE1102	Engineering Plastics	PC	3	3	0	0	3
3	PE1103	Macromolecular Science	PC	3	3	0	0	3
4	PE1104	Polymer Processing Technology cum laboratory	PC	3	3	0	2	4
5		Professional Elective I	PE	3	3	0	0	3
6		Professional Elective II	PE	3	3	0	0	3
		PRACTICALS						
7	PE1111	Macromolecular Science Laboratory	PC	4	0	0	4	2
			TOTAL	22	18	0	6	21

SEMESTER-II

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
		THEORY						
1	PE1201	Evaluation and Testing of Polymers	PC	3	3	0	0	3
2	PE1202	Polymer Additives and Compounding	PC	3	3	0	0	3
3	PE1203	Polymer Product Manufacturing	PC	3	3	0	0	3
4	PE1204	Polymer Products and Mould Design	PC	3	3	0	0	3
5		Professional Elective III	PE	3	3	0	0	3
6		Professional Elective IV	PE	3	3	0	0	3
		PRACTICALS						
7	PE1211	Polymer Testing Laboratory	PC	4	0	0	4	2
8	PE1221	Seminar	EEC	2	0	0	2	1
			TOTAL	24	18	0	8	21

SEMESTER-III

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
		THEORY						
1	PE1301	Advanced Composites Technology	PC	3	3	0	0	3
2		Professional Elective V	PE	3	3	0	0	3
3		Open Elective -I	PE	3	3	0	0	3
4		Online Course (NPTEL / SWAYAM)	OC	0	0	0	0	3
		PRACTICALS						
5	PE1321	Project Work (Phase I)	EEC	12	0	0	12	6
6	PE1322	Industrial Training (4 Weeks)	EEC	0	0	0	0	1
			TOTAL	21	9	0	12	19

SEMESTER-IV

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
		THEORY						
1	PE1421	Project Work (Phase II)	EEC	24	0	0	24	12
			TOTAL	24	0	0	24	12

Semester wise Credits	I	II	III	IV	Total Credits
	21	**21**	**19**	**12**	**73**

PROFESSIONAL ELECTIVE COURSES (PE)
SEMESTER-I, PROFESSIONAL ELECTIVE – I

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1	PE1131	Advanced Polymer Rheology	PE	3	3	0	0	3
2	PE1132	Applied Mathematics	PE	3	3	0	0	3
3	PE1133	Industrial Chemical Processes	PE	3	3	0	0	3
4	PE1134	Packaging & Decoration of plastics	PE	3	3	0	0	3

SEMESTER-I, PROFESSIONAL ELECTIVE – II

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1	PE1135	Advanced Moulding Technology	PE	3	3	0	0	3
2	PE1136	Advanced Polymer Synthesis	PE	3	3	0	0	3
3	PE1137	Reaction Engineering	PE	3	3	0	0	3
4	PE1138	Research Methodology	PE	3	3	0	0	3

SEMESTER-II, PROFESSIONAL ELECTIVE – III

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1	PE1231	Additive manufacturing	PE	3	3	0	0	3
2	PE1232	Characterization of Macromolecules	PE	3	3	0	0	3
3	PE1233	Fiber science and Technology	PE	3	3	0	0	3
4	PE1234	Industrial Management	PE	3	3	0	0	3

SEMESTER-II, PROFESSIONAL ELECTIVE – IV

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1	PE1235	Computer Aided Design Mould & Die Manufacturing	PE	3	3	0	0	3
2	PE1236	Intellectual Property Rights and Copyright Laws	PE	3	3	0	0	3
3	PE1237	Polymer Degradation and Stabilization	PE	3	3	0	0	3
4	PE1238	Speciality and Functional polymers	PE	3	3	0	0	3

SEMESTER-III, PROFESSIONAL ELECTIVE – V

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1	PE1331	Adhesives science and Sealants Technology	PE	3	3	0	0	3
2	PE1332	Polymer Multiphase Systems	PE	3	3	0	0	3
3	PE1333	Process Instrumentation	PE	3	3	0	0	3
4	PE1334	Smart Materials	PE	3	3	0	0	3

SEMESTER-III, Open ELECTIVE – I (Offered by Polymer department)

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1	OPE151	High Performance Polymers	PE	3	3	0	0	3
2	OPE152	Industrial safety	PE	3	3	0	0	3
3	OPE153	Polymer Engineering	PE	3	3	0	0	3
4	OPE154	Polymers in Electrical & Electronics applications	PE	3	3	0	0	3

PROFESSIONAL CORE COURSES (PC)

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1	**PE1101**	Elastomer Technology	PC	3	3	0	0	3
2	**PE1102**	Engineering Plastics	PC	3	3	0	0	3
3	**PE1103**	Macromolecular Science	PC	3	3	0	0	3
4	**PE1104**	Polymer Processing Technology cum laboratory	PC	3	3	0	2	4
5	**PE1111**	Macromolecular Science Laboratory	PC	4	0	0	4	2
6	**PE1201**	Evaluation and Testing of Polymers	PC	3	3	0	0	3
7	**PE1202**	Polymer Additives and Compounding	PC	3	3	0	0	3
8	**PE1203**	Polymer Product Manufacturing	PC	3	3	0	0	3
9	**PE1204**	Polymer Products and Mould Design	PC	3	3	0	0	3
10	**PE1211**	Polymer Testing Laboratory	PC	4	0	0	4	2
11	**PE1301**	Advanced Composites Technology	PC	3	3	0	0	3

Employability Enhancement Courses (EEC)

S.NO	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1	**PE1221**	Seminar	EEC	2	0	0	2	1
2	**PE1321**	Project Work (Phase I)	EEC	12	0	0	12	6
3	**PE1322**	Industrial Training (4 Weeks)	EEC	0	0	0	0	1
4	**PE1421**	Project Work (Phase II)	EEC	24	0	0	24	12

S. No.	Category of Courses	I	II	III	IV	Credits
1.	**Foundation Courses (FC)**	-	-	-	-	-
2.	**Professional Core Courses (PC)**	15	14	3		32
3.	**Professional Elective Courses (PE)**	6	6	3		15
4.	**Open Elective Courses (OE)**			3		3
5.	**Employability Enhancement Courses (EEC)**		1	7	12	20
6.	**Online Courses (OL)**			3		3
Semester wise Credits		21	21	19	12	73
Total Credits						**73**

PE1101	ELASTOMER TECHNOLOGY	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To impart knowledge in predicting and modifying the properties of rubber.
- To provide understanding on rubber compounding ingredients, their importance
- To make students familiar in different rubber materials
- To develop an understanding of the properties and application of various rubbers

UNIT I INTRODUCTION TO RUBBERS 9

Basics*:* Criteria for a polymer to behave as a rubber – structure vs Tg, chemical, mechanical and electrical properties - Classification of rubbers .

Structure property relationship: Effect of structure on Tg – Effect of chemical structure on the performance properties of rubbers – Effect of structure on processing properties of elastomers

UNIT II COMPOUNDING AND MIXING 9

Compounding ingredients: General principles of rubber compounding – Various compounding ingredients and their classification – Preparation, properties and uses of carbon black – Non-black fillers, plasticizers, accelerators, activators, cross-linking agents – Special purpose additives

Mixing Devices: Rubber mixing mechanism– Mixing machinery

UNIT III GENERAL PURPOSE RUBBERS 9

General purpose rubbers**:** Natural rubber latex, tapping – Conversion to dry rubber – Properties, grading and specifications of NR – Chemically modified NR – SBR: preparation, types, properties and applications– BR: polymerization, properties and applications – IR: Manufacture, properties and applications – poly alkenamers, polynorbornenes

UNIT IV SPECIAL PURPOSE RUBBERS 9

Specialty elastomers: Manufacture, Properties and Application: IIR– EPRs– NBR– CR– HNBR– ACM– EMA–EVA– CSM– CM– epichlorohydrin rubbers – polysulphide rubbers.

UNIT V HIGH PERFORMANCE AND THERMOPLASTIC ELASTOMERS 9

High performance elastomers**:** Manufacture, Properties and Application: Silicone Elastomers– Fluorocarbon rubbers – Polyurethane Rubbers

Thermoplastic elastomers*:* Requirements for thermoplastic elastomeric behaviour – Different methods of preparation – SBS and SIS Block copolymers – Thermoplastic Polyurethane elastomers – Thermoplastic – copolyesters – Thermoplastic elastomers based on Plastics – Rubber Blends – Dynamic Vulcanization

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Predict the properties of rubbers based on their chemical structure and modify it as per property requirement.

CO2: Select proper vulcanization mechanism for a particular rubber compound to meet desired product performance.

CO3: Select suitable grades of general purpose rubbers for the desired application

CO4: Apply the knowledge of various rubbers and select an appropriate rubber for a given application.

CO5: Choose a suitable rubber for high-performance applications

REFERENCES:

1. Bhowmick, A.K., and Stephens, H.L., 2001. *Hand Book of Elastomers*. 2nd ed. New York: Marcel Dekker.

2. Kothandaraman, B., 2010. *Rubber Materials*. New Delhi: Ane Books Pvt. Ltd.

3. Brydson, J. A.. 1978, *Rubber Chemistry*, Applied Science Publishers,

4Martin, J.M.,and.Smith, W.K., 2004. *Handbook of Rubber Technology*. Vol. 1 & 2, CBS Publishers & Distributors.

4. Maurice Morton., 1987*. Rubber Technology*, Van Nostrand Reinhold.

PE1102	ENGINEERING PLASTICS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To acquire knowledge of polymers meant for electrical, electronics and high temperature applications.
- To impart basic knowledge on polymer blends, alloys and liquid crystals.
- To gain knowledge of polymers in lithography, water treatment and biomedical applications

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 – ultrahigh fibres – aramids – technora – carbon fibres.

UNIT III POLYMER BLENDS, ALLOYS AND LIQUID CRYSTALS 9

Polymer blends and alloys – reinforced plastics – ionic polymers –interpenetrating networks – sequential – simultaneous – full and semi IPN – thermoplastic IPN – liquid crystalline polymers (LCP) – lyotropic and thermotropic liquid crystals – main chain and side chain liquid crystalline polymers–processing of LCP's- applications – ablative plastics.

UNIT IV POLYMERS IN LITHOGRAPHY AND WATER TREATMENT 9

Polymers in lithography – photoresist – positive resists – negative resists – solution inhibition resists – image reversal process – Ion exchange resins – 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

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Apply polymers to electrical, electronics and high temperature fields.

CO2: Select the polymers for high temperature application

CO3: Use the polymer blends, alloys and liquid crystals in suitable engineering application

CO4: identify the polymers for lithography and water treatment applications.

CO5: Choose the polymers for bio medical fields membrane, bone cement, tissue engineering and drug delivery applications.

REFERENCES:

1. Mark, H.F. and Kroschwitz, J.I., 1985. *Encyclopedia of polymer science and engineering*.

2. Chapoy (Ed), L.L. 1985. *Recent Advances in Liquid Crystalline Polymers*, Chapman and Hall, London.

3. Dyson, R.W. 1998. *Specialty Polymers, Blackie Academic & Professional*, London, (second edition).

4. Wong, C.P.1993. *Polymers for Electronic and Photonic Applications*, Academic Press, New York.

PE1103	MACROMOLECULAR SCIENCE	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To introduce the fundamentals of polymer chemistry, structure and classification of polymers.
- To impart knowledge about preparation , properties and application of bio and inorganic polymers
- To provide exposure about chain polymerization methods with importance
- To acquire knowledge in the step growth polymerizations and copolymerization and polymerization reactions.
- To develop an understanding of molecular weight and solubility of macromolecules.

UNIT I FUNDAMENTALS OF POLYMERS 9

Basics – Monomer, polymer, oligomer, initiator, functionality-Polymer classifications based on- occurrence, types, process, structure and end uses. Polymerization techniques-bulk-solution-suspension and emulsion. Effect of Structure in property (optical, thermal, mechanical, electrical etc.) relationships.

Polymer microstructure-chemical and geometrical structure - ladder, star and telechelic polymers – interpenetrating networks –tacticity –crystalline-amorphous nature- crystallization.- crystallizability-effect on properties

UNIT II BIO AND INORGANIC POLYMERS 9

Naturally occurring polymers – starch, proteins, cellulose – Derivatives of cellulose polymers – rayon, cellophane, cellulose acetate, butyrate and nitrate – ethyl cellulose – carboxymethyl cellulose- preparation, properties- application.

organo metallic polymers - co-ordination polymers

Inorganic polymers - phosphorous and nitrogen containing polymers, – silicones - hybrid polymers

UNIT III CHAIN POLYMERIZATION AND POLYMERIZATION TECHNIQUES 9

Kinetics and mechanism of free radical, cationic, anionic and coordination polymerization –Ziegler Natta catalysts-monometallic mechanism- stereo regular polymerization – chain transfer reaction and constant – living polymers – Alfin catalysts – iniferters- comparison of radical cationic and anionic polymerizations.

Advanced Polymerization techniques: Atom Transfer Radical Polymerization (ATRP)- Group Transfer Polymerization (GTP)-Reversible Addition Fragmentation Termination (RAFT)- click polymerization-green polymerization concepts.

UNIT IV STEP GROWTH POLYMERIZATIONS AND COPOLYMERIZATION 9

Polycondensation polymerization – Step polymerization, Kinetics and mechanism of step growth polymerization-reactivity of functional groups, need for stoichiometric control, gelation, crosslinking, Carother's equation

Copolymerization, chain copolymerization, introduction, types, copolymerization equation, monomer reactivity ratio, types of copolymerization behavior.

Polymerization reactions- mathematical, electrochemical and ring opening.

UNIT V MOLECULAR WEIGHT, SOLUBILITY OF POLYMERS 9

Molecular weight types - Molecular weight averages - Molecular weight distribution - Unidispersity, polydispersity, Degree of polymerization. Effect of Molecular weight on processing and properties- Factors affecting molecular weight and molecular weight distribution

Determination of molecular weight by GPC, viscometry.Light scattering, end group analysis.

Polymer dissolution - thermodynamics of polymer dissolution - solubility parameter

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Apply the knowledge of fundamentals of macromolecular chemistry in engineering

CO2: Apply the knowledge in synthesizing bio and inorganic polymers

CO3: Select suitable polymerization techniques and knowledge of kinetics of chain polymerization.

CO4: State step growth polymerizations, copolymerization and polymerization reactions

CO5: Find molecular weight and solubility of polymers.

REFERENCES:

1. Billmeyer, F.W., 1984. *Textbook of polymer science*. John Wiley & Sons
2. Odian, G., 2004. *Principles of polymerization*. John Wiley & Sons.
3. Bhatnagar,M.S., 2007, *A Text Book of Polymers (Chemistry and Technology of Polymers), Vol I, II & III,* S.Chand and Company.

4Ghosh, P., 1990. *Polymer science and technology*. Tata McGraw-Hill Education..

5. Young, R.J. and Lovell, P.A., 2011. *Introduction to polymers*. CRC press.
6.Fried; J. R.,2003, *Polymer Science and Technology,* Prentice-Hall of India Pvt. Ltd.,
7. Peacock, A.J. and Calhoun, A., 2012. *Polymer Chemistry: Properties and Application*. Carl Hanser Verlag GmbH Co KG
8.Ravie, A. 2012. *Principles of Polymer Chemistry,* Springer-Verlag.
9. Carraher C E,2017., *Introduction to Polymer Chemistry*, CRC Press.
10. Gowarikar V.R.,2015. *Polymer Science*, New Age International Pvt. Ltd.

PE1104	POLYMER PROCESSING TECHNOLOGY cum LABORTORY (*Theory cum Lab)*	L	T	P	C
		3	0	2	4

OBJECTIVES:

- To impart in-depth knowledge on different methods of in injection molding, Blow molding and extrusion process.
- To make the students to acquire knowledge in Rotational molding, Thermoforming and Compression molding and transfer moulding process
- To enable students to get hands on experience on the processing of polymers

UNIT I EXTRUSION 9

Extrusion- Principle - Types of Extruders - Single screw and twin-screw extruders – Role of Breaker Plate and Screen Pack-Composition and Extrusion of PVC Pipes, Nylon Filaments, PVC Profiles, Polyethylene Blown films and PVC Wire coating.

Exp:

a) Scrap grinding of plastics waste
b) Recycling of thermoplastics using Extrusion process

UNIT II BLOW MOULDING 9

Blow moulding – Fundamentals of the process, complete blow moulding operation, Extrusion blow moulding, Injection blow moulding & Stretch blow moulding.
Polymer material selection for blow moulding: HDPE, PP, PET, Nylon, EVA and EVOH-Parison wall thickness control-Process parameters and their effect on product quality.

Exp: Blow Moulding of Bottles

UNIT III THERMOFORMING AND ROTATIONAL MOULDING 9

Thermoforming – Basic process, material selection for thermoforming- methods of forming : simple vacuum forming, drape forming, pressure forming, snap back forming, plug-assist forming and matched mold forming.
Rotational moulding – Basic principle- Types: Shuttle type-Swing arm type-Carousel type-Clamshell type-Rock and roll type;

UNIT IV COMPRESSION AND TRASFER MOULDING 9

Compression moulding – Basic principle – Types - Machinery and equipment- Type of compression mould, Automatic compression molding- Advantages & limitations.
Transfer moulding – Types – Pot type-Plunger type-Screw transfer type- Processing behavior of Phenol formaldehyde, Urea Formaldehyde and Melamine formaldehyde.
Exp: Compression moulding of polymers

UNIT V INJECTION MOULDING 9

Introduction to polymer processing - Plastics process techniques - Injection moulding – Principle- Types of Injection unit – Types of Clamping unit- Clamping tonnage calculation.

Processing behavior and injection moulding conditions for Polyethylene, Polypropylene, Nylon, PBT, Polycarbonate, ABS and PMMA - Trouble shooting operations

Exp:

a) Injection moulding of Bottle caps
b) Injection molding of L-Joints
c) Injection molding of T-Joints
d) Injection molding of Drainage Filter

TOTAL: 45+30=75 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Suggest suitable polymer materials for making of extruded pipes, films, sheets and profiles

CO2: Apply blow molding principles to make polymer products

CO3: Compare the thermoforming and rotational molding principles to make polymer products

CO4: Differentiate compression moulding and Transfer moulding process

CO5: Apply the injection molding principles to make polymer parts

REFERENCES:

1. Kumar, A. and Gupta, R.K., 2018. *Fundamentals of polymer engineering*. CRC Press.
2. Agassant, J.F., Avenas, P., Carreau, P.J., Vergnes, B. and Vincent, M., 2017. *Polymer processing: principles and modeling*. Carl Hanser Verlag GmbH Co KG.
3. Baird, D.G. and Collias, D.I., 2014. *Polymer processing: principles and design*. John Wiley & Sons.
4. Lafleur, P.G. and Vergnes, B. eds., 2014. *Polymer extrusion*. John Wiley & Sons.
5. Rosato, D.V. and Rosato, M.G., 2012. *Injection molding handbook*. Springer Science & Business Media.
6. Thomas, S. and Yang, W. eds., 2009. *Advances in polymer processing: from macro-to nano-scales*. Elsevier.
7. Tadmor, Z. and Gogos, C.G., 2013. *Principles of polymer processing*. John Wiley & Sons.
8. Crawford, R.J. and Martin, P.J., 2020. *Plastics engineering*. Butterworth-Heinemann.
9. Cheremisinoff, N.P. and Cheremisinoff, P.N., 1996. *Handbook of applied polymer processing technology* (Vol. 31). CRC Press.

PE1111	MACROMOLECULAR SCIENCE LABORATORY	L	T	P	C
		0	0	4	2

OBJECTIVES:

- To make the student conversant with polymer synthesis, and appreciate the kinetics of polymerization.
- To enable students understand the methods preparation of polymer by various polymerization method..
- To determine the molecular weight, volatile, moisture content of polymers.

LIST OF EXPERIMENTS

Part –A Preparation

1. Preparation of styrene by bulk polymerization
2. Preparation of styrene –acrylonitrile by bulk polymerization.
3. Preparation of methylacrylate by emulsion polymerisation
4. Preparation of styrene by suspension polymerizaiton
5. Preparation of acrylnonitrile by solution polymerization
6. Preparation of poly acrylamide by free radical polymerization.
7. Synthesis of urea - formaldehyde by condensation polymerization.
8. Preparation of polyaniline.
9. Synthesis of polysulphide rubber.

Part –B Determination

1. Determination of reactive ratio for copolymerisation of styrene with MMA
2. Determination of Molecular weight and its distribution using viscometry, end group analysis, GPC,osmometry, VPO.
3. Determination of volatile mater of polymer
4. Determination of moisture content of polymer
5. Identification of polymers - Plastic and Rubbers

(Any four experiments in Part –A and Part –B each)

TOTAL: 60 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Apply the theoretical knowledge to prepare the polymers

CO2: Synthesize polymers and copolymers by using different polymerization techniques

CO3: Analyze qualitatively the prepared polymers

CO4: Identify the polymers by physical and chemical method

CO5: Determine the molecular weight of polymers

REFERENCES:

1. Collins, E.A., Bares, J. and Billmeyer, F.W., 1973. Experiments in polymer science.

2. Osswald, T.A. and Menges, G., 2012. *Materials science of polymers for engineers*. Carl Hanser Verlag GmbH Co KG.
3. Wayne R.Sorenson and Campbell, T.W. 2001. *Preparative Methods of Polymer Chemistry*
3rd edition, Wiley – Interscience, New York.
4. McCaffery E.M. 1970, *Laboratory Preparation for Macromolecular Chemistry*, McGraw Hill,Kogakush.

LIST OF EQUIPMENT FOR A BATCH OF 30 STUDENTS:

S. No.	Description of Equipment	Quantity Required
1.	Glassware for reactions	Sufficient
2.	Osmometer	3
3.	Ubbelhode viscometer	3
4.	VPO	1

PE1201 EVALUATION AND TESTING OF POLYMERS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To impart the knowledge of various characterizations methods
- To develop knowledge of National & International standards for polymer testing and mechanical properties of polymers
- To enable the student learn about thermal and electrical properties of polymers
- To acquire knowledge in the field of optical properties, weathering and chemical test
- To enable the students to learn about the property of the plastic material for several applications.

UNIT I CHARACTERIZATION TESTS 9

Introduction, principle and application of Fourier transform infrared spectrometry, Ultraviolet - visible spectrometry, Contact angle, Scanning electron microscopy, transmission electron microscopy

UNIT II TESTING ORGANIZATIONS AND MECHANICAL PROPERTIES 9

Standards: National and International standards in the field like BIS, ASTM, DIN, ISO etc. – Test specimen preparation

Raw materials characterization - melting point, density, viscosity, melt flow index, K-value.

Mechanical Properties - stress-strain behavior in shear strength, tensile strength,

compressive strength, flexural strength, Impact- Izod, Charpy, hardness, abrasion resistance, resilience

UNIT III THERMAL AND ELECTRICAL PROPERTIES 9

Thermal Properties

Principle, Instrument, and application of - Differential Scanning Calorimetry (DSC), Differential thermal analysis (DTA), Thermogravimetric analysis (TGA), thermal conductivity - Heat deflection temperature – Vicat softening temperature – coefficient of thermal expansion-shrinkage– Thermal ageing

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

UNIT IV OPTICAL, CHEMICAL and WEATHERING PROPERTIES 9

Optical Properties

Interaction of light with polymers reflection and refraction of light by polymers (Refractive index, haze, clarity, gloss, colour), birefringence, Gas and Water vapour permeability test

Chemical Properties

Stain resistance – ESCR

Weathering Test

Accelerated weathering test – Outdoor weathering test –Fungi and Bacteria resistance

UNIT V PROCESSABILITY and PRODUCT TESTING 9

Processability Test

Mechanical stability, Plasticity, plasticity retention index (PRI), scorch time and cure characteristics (Mooney viscometer, oscillating disc rheometer)

Product testing: film, Pipe, tube, blow bottle testing , Laminates

Non-destructive testing: ultrasonic testing, acoustic properties, X-ray fluorescence

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Understand the significance and can suggest the techniques which are used for analysis of Polymers such as IR, UV and Interpret and analyze the given data of any compound.

CO2: gets knowledge about organization standard and mechanical properties of polymers

CO3: acquire knowledge on thermal and electrical properties of polymers

CO4: Demonstrate the optical and chemical properties of polymers

CO5: Perform various tests for evaluating the properties of plastic materials.

REFERENCES:

1. Mathur, A. B. and Bharadwaj, I.S., 2003. *Testing and Evaluation of Plastics.* Allied Publishers Pvt. Ltd, New Delhi.

2. Malkin, A. Ya., AskaDsky, A.A. and Koverica, V.V., 1998. *Experimental methods of polymers*. Mir Publishers, Moscow.
3. Sivasankar, B., 2012. *Engineering Chemistry*. Tata McGraw-Hill Publishing Company Ltd, New Delhi.
5. S. K. Nayak, S.K., Yadav, S.N. and Mohanty, S., 2010. *Fundamentals of Plastic Testing.* Springer.
6. Vishu Shah., 2007. *Hand book of Plastics Testing and Failure Analysis.* John-Willey & Sons, New York.
7. Roger Brown., 2006. *Physical Testing of Rubber*. Springer.

PE1202 POLYMER ADDITIVES AND COMPOUNDING L T P C

3 0 0 3

OBJECTIVES:

- To enable students know about various additives like Lubricants, Fillers, Fibres, flame retardants, colorants anti oxidants, UV-stabilizers, plasticizers, anti blocking agents, Nucleating agents, Flow promoters, Anti static agents etc.
- To make them understand the functions of each of these additives, technical requirements, types & mechanism, and their effective evaluation are dealt with in this subject.
- To enable them select suitable plastics material compounding and mixing techniques like two roll milling, internal blender, single / twin screw extruder, etc

UNIT I INTRODUCTION TO COMPOUNDING AND ADDITIVES 9

Introduction- limitations of polymeric materials. Additives- technological requirements of additives. - Fundamentals of Compounding, Essentials of Compounding, Compounding of plastics and rubber.
Classification-Chemistry and Mechanism- Selection Criteria-General effect on Properties-Evaluation and functions of additives - Antioxidants- Stabilizers (Heat & UV)- carbon black-its types, manufacture and characteristics-mechanism of reinforcement of a rubber, non black fillers in rubbers

UNIT II ADDITIVES FOR PLASTICS 9

Plasticizers-Fillers and reinforcements - Impact Modifiers-Lubricants – Antistatic agents- Antiblocking agents - processing aids - Blowing agents-Flame Retardants – Masterbatch- Colourants. –Nucleating agents

UNIT III ADDITIVES FOR THERMOSET AND COMPOSITES 9

Compounding of thermosets - unsaturated polyester resins – epoxy resins – compounding of moulding powders – phenol formaldehyde – melamine formaldehyde
Additives for Composites - Catalysts - Accelerators – Coupling Agents - Fillers - Toughening Agents

UNIT IV EQUIPMENT FOR COMPOUNDING 9

Single screw extruders – twin-screw extruders – internal and external mixers - high-speed fluidized mixer and cooler - mixing machinery for rubbers – two roll mill – internal batch mixers – continuous mixers – Banbury mixer - operations and maintenance of mixing equipment

UNIT V MECHANISM OF MIXING AND COMPOUNDING TECHNIQUES 9

mechanism of mixing and dispersion, mixing of solid-solid, liquid-liquid and liquids-solids, dispersive mixing, distributive mixing,

Selection of Polymers and Compounding ingredients- Methods of incorporation of additives into Polymer materials, Compounding of PVC, PE and PP, morphology of filler, compatibilizers – mechanism and theory, filler surface modification and interfacial agents

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1.explain the basics of compounding and additives of polymers

CO2. select a suitable additive for a plastic

CO3. identify additive for suitable composite and compounding of thermosets

CO4.find suitable equipment compounding of polymers

CO5. apply the knowledge of mechanism of mixing and compounding techniques for a polymer

REFERENCES

1. John Murphy, 2001. *The Additives for Plastics Hand Book*, Oxford: Elsevier Advanced Technology..

2. Brydson, J.A., 1999. *Plastics Materials,* 7th ed. Oxford: Butterworth Heinemann.

3. Dr.Muralisrinivasan Natama Subramanian., 2014. *Introduction to Polymer Compounding: Raw Materials.*

4.Jesse Edenbaum., 1996. *Plastics Additives and Modifiers Hand Book* London.Chapman & Hall.

5.Ica Manas – Zloczower., and Zehev Tadmor., 1995. *Mixing and Compounding of Polymers*, Munich,Hanser Publications.

6.Nicholas P. Cheremisionoff., 1995. *Polymer Mixing and Extrusion Technology*, NewYork Marcel Dekker Inc.,.

7. Gachter., R.. and Muller H., 1993. *Plastics Additives Hand Book*, Munich. Hanser Publishers, ,

PE1203 POLYMER PRODUCT MANUFACTURING

L	T	P	C
3	0	0	3

OBJECTIVES:

- To enable the students to learn the manufacturing technique for tyres.
- To make the student to acquire knowledge in Manufacturing of belts, hoses and oil seals
- To impart knowledge in automotive interior and exterior polymer parts manufacturing techniques

UNIT I TYRE MANUFACTURING 9

Tyre- Introduction- Components- functions and requirements– Composition for tyres - Various Types – Bias – Belted – Radial – Tubeless Tyre - Solid tyres – Tyre Building- Manufacturing methods – moulding & vulcanization.

UNIT II BELT AND HOSES MANUFACTURING 9

Belting- Conveyor belting - Components and Functions – Building & Manufacturing of V Belts-Classical V Belts-Banded V Belts-Cogged V Belts. Hoses – Types-Manufacturing of moulded hose, machine made hose & Hand built hoses

UNIT III OIL SEALS AND ENGINE MOUNT MANUFACTURING 9

Manufacturing, curing of Oil Seals, Gaskets, Engine Mounts, Bridge pads and railway pads- Rubber to Metal bonding - Good manufacturing practices - Effluent-Control and Treatment- Safety in rubber industry

UNIT IV AUTOMOTIVE INTERIOR PARTS MANUFACTURING 9

Automotive Interior Parts – Polymer Material selection - Manufacturing of Automotive interior polymer parts : Instrumental panel, Door Panel, Air vent, Console, Seating, Door Trim, Steering wheel, airbags & pedals.

UNIT V AUTOMOTIVE EXTERIOR PARTS MANUFACTURING 9

Automotive Exterior Parts –Polymer Material selection - Manufacturing of Automotive Exterior polymer parts: Body panels and structure, Bumpers, Grills, Spoilers, Mirror housing, Door handles & Sun roof components.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Compare the various types of tyres and its manufacturing techniques

CO2: Classify belts and hoses suitable polymer composition for making belts and hoses

CO3: Demonstrate the manufacturing of oil seals and engine mounts

CO4: Select suitable molding techniques for automotive exterior parts

CO5: Suggest suitable molding techniques for automotive interior parts

REFERENCES:

1. Bhowmick, A. ed., 2018. *Rubber products manufacturing technology*. Routledge.
2. Stauber, R., 2007. Plastics in automotive engineering. *ATZ worldwide*,
Maxwell, J., 1994. *Plastics in the automotive industry*. Elsevier.
3. Sehanobish, K., 2009. *Engineering plastics and plastic composites in automotive applications* (Vol. 122). SAE Technical Paper.
4. Thomas, S. and Yang, W. eds., 2009. *Advances in polymer processing: from macro-to nano-scales*. Elsevier.
5. Koronis, G. and Silva, A. eds., 2018. *Green Composites for Automotive Applications*. Woodhead Publishing.
6. Crawford, R.J. and Martin, P.J., 2020. *Plastics engineering*. Butterworth-Heinemann.

PE1204	POLYMER PRODUCTS AND MOLD DESIGN	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To impart the knowledge on design factor involved in a polymer product manufacture.
- To aware the behaviour of polymer product
- To impart the knowledge on design of mold and die for polymer products.

UNIT I DESIGN PRINCIPLES 9

Introduction, design principles, Procedure and steps in product design, Stress –strain response of Polymer, Polymer structure- physical and chemical properties, effect of fillers on properties. *Design features of products* - corners, wall thickness, ribs, tapers, draft angles, weld lines

UNIT II DESIGN FOR STRESS & APPLICATION 9

Stress and long term property analysis, stress in products- tension, compression and shear, effect of cyclic loading, structural design of products under static and dynamic loads, design of beams and plates, design for stiffness, design for electrical application, design for optical application.

UNIT III DESIGN CONSIDERATION 9

Gear Design materials strength and durability, moulded vs cut plastics gear inspection assembly and operation. *Bearings*: Self lubricated plastic materials rubber bearing, type of bearings, designers check list. *Elastomeric ring seals* - basic configurations, design method, design consideration static and dynamic seals

UNIT IV INJECTION MOLD COMPONENTS 9

Design features of standard mold components, materials used for Mold, *Calculations* for number of cavities based on clamping tonnage, shot weight. Feed system: types of runners, runner layout, calculation of runner efficiency, runner design; runner balancing, types of gates. Different methods of ejection, Cooling system.

UNIT V COMPRESSION, TRANSFER AND DIE DESIGN **9**

Types of compression moulding process-Determination of number of cavities-design of mould cavity, design of loading chamber-Transfer mould design- Extrusion die design-Construction features of an extruder, solid die-wire and cable die- Pipe die.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Predict the structure and properties of polymers for design aspect
CO2: Modify the products designs for stiffness
CO3: Demonstrate design of rubber and plastics products
CO4: Examine the design components in Injection mould
CO5: Illustrate the design of compression, transfer mold and dies

REFERENCES:

1.Miller Edward, Marcel Dekker, 2006. *Plastics Products Design Hand Book*, Hanser Pub.

2. Laszlo Sors and ImreBalazs, 1989. *Design of Plastics Moulds and Dies*, Elsevier, Amsterdam Oxford - Tokyo – NY.

3.Cracknell, P.S. and Dyson, R.W., 1993. *Handbook of thermoplastics injection mould design*. Kluwer Academic Pub.

4. S.Levy& Dubois,J.H.,1977. *Plastic Product Design Engineering Hand Book*, Van Nostrand Reinhold Co., New York.

PE1211	POLYMER TESTING LABORATORY	L	T	P	C
		0	0	4	2

OBJECTIVES:

- To learn the characterization methods to study the thermal & structural characteristics of polymers using DSC & TGA.
- To evaluate the basic mechanical and thermal properties of the polymer.
- To get practice in testing of electrical & optical Properties of plastics materials.
- To learn the physical test for polymers
- To get practice in testing of plastics products like pipes, water tanks, etc.

LIST OF EXPERIMENTS

CHARACTERIZATION TEST (ANY TWO)

1.To determine the of Melt Flow Index of different Plastics Materials.

2. To Characterize the Weight loss of polymers by Thermogravimetric, Analysis, (TGA).

3. To determine the Tg of polymers by Differential Scanning Calorimetry (DSC).

4. Study of UV stabilization of polymer samples by UV-visible spectrophotometer

MECHANICAL PROPERTIES & THERMAL PROPERTIES

(ANY FIVE)

5.To determine the tensile strength at break & yield & % elongation of dumbbell shaped specimens of various polymers

6. To determine the Izod impact strength for various polymer

7. To determine the falling dart impact strength for films

8. To determine the shore A and Shore D for rubber and plastics

9. To determine the abrasion test for rubber and plastic

10. To determine the heat deflection temperature.

11. To determine the Vicat softening temperature

UNIT III ELECTRICAL PROPERTIES & CHEMICAL PROPERTIES

(ANY TWO)

12. To determine the volume & surface resistivity of plastic and rubber sample.

13. To determine the dielectric strength of sample

14. To find the arc resistance of sample

15. To find out environmental stress crack resistance for polyethylene and other polymeric samples.

16. To determine the chemical resistance of sample

PHYSICAL PROPERTIES (ANY TWO)

17. To determine the Ash Content in plastics materials.

18. To find the Moisture Content in plastics materials.

19. To determine the specific gravity of rubber sample and other polymeric samples.

20. To carry out water absorption test for various polymers.

PLASTIC PRODUCT TESTING (ANY FOUR)

21. Testing of HDPE & UPVC Pipes

22. Testing of Water Storage Tanks

23. Testing of Films/Sheets

24. Testing of HDPE/PP Woven Sacks/Tapes

25. Testing of Baby Feed Bottles

26. Testing of Milk Packing Pouches

27. Testing of FRP Sheets

TOTAL: 60 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Analyze and interpret the output of DSC & TGA to elucidate the thermal behavior of the polymers

CO2: Test the mechanical and thermal Properties of plastics materials.

CO3:Demonstrate the electrical and optical properties of polymers

CO4: Examine the physical properties of materials

CO5: Test plastics products like pipes, water tanks.,etc and plastics films, tapes, woven sacks

REFERENCES:

1. Campbell, D. and White, J.R., 2017. *Polymer Characterization: Physical Techniques.* Chapman & Hall, London. .

2. Willard., Dean. and Merritt, 2004. *Instrumental methods of analysis.* Wadsworth Publication.

3. Billmeyer, W., 2004. *Text book of Polymer Science.* Wiley-Interscience.

4.Vishu Shah., 2007. *Hand book of Plastics Testing and Failure Analysis.* John-Willey & Sons, New York.

5. Roger Brown., 2006. *Physical Testing of Rubber*. Springer.

6. Nayak., S.K., Yadav., S.N. and Mohanty., S. 2010. *Fundamentals of Plastic Testing*, Springer.

LIST OF EQUIPMENT FOR A BATCH OF 30 STUDENTS:

S. No.	Description of Equipment	Quantity Required
1.	Melt flow index apparatus	1
2.	Environmental stress cracking resistance tester	1
3.	Universal testing machine	1
4.	Impact strength tester	1
5.	Shore A – Hardness tester	1
6.	Shore D – Hardness tester	1
7.	Abrasion resistance tester	1
8.	Heat deflection temperature tester	1
9.	Vicat softening point tester	1
10.	Volume & Surface resistivity testing apparatus	1
11.	Dielectric strength tester	1
12.	Arc Resistance tester	1
13.	Specific Gravity tester	1

14.	Differential Scanning Calorimeter	1
15.	Thermo Gravimetric Analyser	1
16.	UV Spectrometer	1

PE1221 **SEMINAR** **L T P C**
0 0 2 1

OBJECTIVES:

The seminar power point presentation shall be fundamentals oriented and advanced topics in the polymer engineering with references of journal papers. Presentation is to be planned for duration of 15 minutes including a question answer session of five minutes. The marks will be awarded based on the presentation of the seminar.

PE1301 **ADVANCED COMPOSITE TECHNOLOGY** **L T P C**
3 0 0 3

OBJECTIVES:

- To impart knowledge of various types of composites and its advantages and needs.
- To understand the various types of fiber materials and its applications for making Composites.
- To understand the knowledge of various resins materials used in processing of composites and the basic destructive and non-destructive testing of composites.

UNIT I INTRODUCTION AND MATRIX FOR COMPOSITES 9

Introduction – Characteristics of composites – Classification – Based on matrix – PMC-MMC-CMC - Reinforcement – particulate, fibrous, laminated, and hybrid composites. Matrix Resins **-** Unsaturated Polyester - Vinyl Ester - Epoxy- Thermoset polyimides- Bismaleimides (BMIs), Cyanate esters (CEs), Benzoxazines and Phthalonitriles- Preparation - Properties and Applications

UNIT II REINFORCEMENT MATERIALS 9

Fibre Reinforcements - Types - CSM – Surface Mats - Performs - Woven and Non Woven

Fabrics – Glass - Carbon - Aramid Fibre - Boron Fibres - Natural Fibres – Cotton – Silk – Wool - Jute – Sisal- Functions of fillers, types, properties, chemistry and applications of fillers such as silica, titanium oxide, talc, mica, silicon carbide, graphite.

UNIT III PROCESSING OF COMPOSITES 9

Processing of thermoplastic composites - Types of processing methods, matched die molding, solution, film, lamination, sandwich. Processing conditions,

advantages and disadvantages**.**

Fabrications of thermoset composites- Hand lay up method, match die molding, compression and transfer molding, pressure and vacuum bag process, filament winding, pultrusion, RIM, RRIM, VARTM & VERTM, Injection moulding of thermosets, SMC and DMC, Advantages and disadvantages of each method.

UNIT IV TESTING AND APPLICATION OF COMPOSITES 9

Testing of Composites - Tensile, Impact, Compression and Flexural Strength- Non Destructive testing for Composites - Application of FRP Products - Products in Aerospace – Marine – Electrical and Electronics – Biomedical – Automobile Industries.

UNIT V LAMINATES FOR COMPOSITES 9

Mechanics of composites-Mechanism of reinforcement and fibre/matrix adhesion-Fracture and damage mechanics - laminates -delamination- Design consideration - sandwich structures-Measurement of physical and mechanical properties: density-fibre volume fraction-void content fibre/matrix interface test

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1.Apply the knowledge of matrix resins in making of composites

CO2. Select suitable fibre reinforcement for composite.

CO3.Apply the knowledge of composite processing and fabrication

CO4.Test the composites and usage of composites for various applications

CO5. Demonstrate the lamination process in composites manufacturing.

REFERENCES:

1.Astrom, B.T., 1997. *Manufacturing of polymer composites*. CRC press.

2.Hollaway, L.C. ed., 1994. *Handbook of polymer composites for engineers*. Woodhead publishing.

3.Hinton, M.J.K.A., Soden, P.D. and Kaddour, A.S. eds., 2004. *Failure criteria in fibre reinforced polymer composites: the world-wide failure exercise*. Elsevier.

4.Peters, S.T. ed., 2013. *Handbook of composites*. Springer Science & Business Media.

PE1321	PROJECT WORK (PHASE –I)	L	T	P	C
		0	0	12	6

Project report: To be prepared in proper format. The report may include the aspects of the literature review. Members of a project group shall prepare and submit the report.

A comprehensive oral Viva-voce examination will be conducted to assess the student's, depth of understanding in the specified field of engineering and technology..etc.

An internal and external examiner is appointed for the Conduct of viva voce end examination.

PE1322	Industrial Training	L	T	P	C
		0	0	0	1

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

Students are required to submit neatly typed and bound training report after joining the college.

The report should include information about working of the industry as also specific information of the work done by the student in the industry. The students are also required to attach the Original Certificate issued by the competent authority from the industry where he / she has undergone training mentioning the successful completion of the training.

The student is required to present the report of the skills / knowledge acquired by her/him during the training for his industrial training evaluation.

PE1421	PROJECT WORK (PHASE –II)	L	T	P	C
		0	0	24	12

Project report: To be prepared in proper format. The report shall record all aspects of the work. Members of a project group shall prepare and submit the report.

A comprehensive oral Viva-voce examination will be conducted to assess the student's intellectual achievement, depth of understanding in the specified field of engineering and technology etc.

An internal and external examiner is appointed for the Conduct of viva voce end examination

PE1131	ADVANCED POLYMER RHEOLOGY	L	T	P	C
		3	0	2	4

OBJECTIVES:

- To understand the basic concepts of rheology
- To analyze the flow behavior of polymer melts and to carry out the experimental techniques for measuring the rheological properties.
- To understand the basics of fluid mechanism and to analyze behavior of newtonian fluids

UNIT I INTRODUCTION TO RHEOLOGICAL PRINCIPALS 9

Introduction to Rheological Principals Classifications of fluids, Newtonian and Non-Newtonian fluids, time independent and time dependent fluids, elastic viscous fluids. Tensor notation system to fluid flow, Shear viscosity, tensile viscosity, effect of temperature & pressure on viscosity.

UNIT II MECHANICAL AND RHEOLOGICAL PROPERTIES 9

Mechanical properties, Definitions – Poisson's ratio, bulk modulus, shear modulus etc, Elastic properties of material – stress strain characteristics, stiffness, tensile strength, yielding in polymers etc, Rubber elasticity, Polymer melt rheology, viscoelsticity.

UNIT III MELT FLOW ANALYSIS 9

Laminar flow thru circular c/s, annulus, slit, parallel plates, irregular profiles. Flow analysis using rheological models like power law, Ellis model. Turbulent flow analysis, turbulence dampling. Viscoelasticity behavior Stress relaxation, relaxation modulus, creep compliance dynamic modulus, dynamic compliance, dynamic viscosity, Mechanical models – Maxwell mode l, Voigt – kelvin model, Zener model, Boltzmann Principle of Superposition

UNIT IV RHEOMETRY STUDY OF ROTATION 9

Rheometry & surface Rheometer. Basic concept of constant stress & constant strain, Different types of Rheometers – Oscillatory Cone and plate Rheometer, Concentric cylinder, parallel disk Rheometer, concentric rotating disk Rheometer, controlled stress rotational Rheometer, Torque Rheometers – Extruder type, sliding plate Rheometers, sliding cylinder Rheometer.

UNIT V RHEOLOGY IN POLYMER PROCESSING OPERATIONS 9

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

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to apply

CO1.Explain the basic rheological principles of polymers

CO 2.Correlate the mechanical and rheological properties of polymers

CO3. Analyse the flow properties of polymers
CO4. Predict the rheometry study of rotation
CO5.Apply the knowledge of rheology in polymer processing operations

REFERENCES:

1.Han, C.D., 2007. *Rheology and processing of polymeric materials: Volume 1: Polymer Rheology* (Vol. 1). Oxford University Press
2.Shaw, M.T., 2012. *Introduction to polymer rheology*. Hoboken, NJ: Wiley.
3.Janeschitz-Kriegl, H., 2012. *Polymer melt rheology and flow birefringence* (Vol. 6). Springer Science & Business Media.
4.Piau, J.M. and Agassant, J.F. eds., 1996. *Rheology for polymer melt processing*. Elsevier.

PE1132	APPLIED MATHAMATICS	L	T	P	C
		3	0	0	3

OBJECTIVES:

The course is aimed to introduce

- The basic knowledge about numerical solutions of Ordinary Differential Equation & Partial Differential Equation, Queuing Models and Probability and Statistics.
- The student to a tool used in analyzing a range of problems arising in the modeling of engineering problems.
- The student for future learning in relation to problem solving and decision making; technical competence; teamwork and leadership; and reflection.

UNIT I NUMERICAL SOLUTION OF ORDINARY DIFFERENTIAL EQUATION 9

Solution of first order Ordinary Differential Equation - Taylors method; Euler Method; Runge Kutta Method of Fourth orders, Predictors – Corrector Methods - Miline and Adams – Bashforths; Introduction to numeric use of the above techniques in plastics engineering and calculations.

UNIT II NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATION 9

Classification of second order linear partial differential equations; Elliptic equation – Solution of Laplace equation – Solution of Poisson's equation; Parabolic equations – Solution of one-dimensional heat equation; Hyperbolic equations – Solution of wave equation.

UNIT III QUEUEING MODELS 9

Poisson Process – Markovian Queues – Single and Multi-server Models – Little's formula – Steady State analysis – Self Service Queue.

UNIT IV PROBABILITY & STATISTICS 9

Probability – Addition theorem, Multiplication theorem; conditional probability – Baye's theorem; Distribution Functions - Binomial distribution - Poisson distribution – Normal distribution - Uniform distribution; Curve fitting – fitting a straight line and second degree curve - Fitting a non linear curve; Correlation and Regression.

UNIT V HYPOTHESIS TESTING 9

Sampling distribution – Large sample and Small samples; Testing of Null hypothesis, Type I and Type II errors; Z test, t test and test - Goodness of fit.; Fisher's F test.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Pedict theories and methods in Ordinary Differential Equations.

CO2: Solve the necessary theories and methods in Partial Differential Equations

CO3: Recognize among others, the Queuing Models which is an efficient tool for solving Engineering problems in an elegant way.

CO4: Apply the basic probability concepts.

CO5: Interpret knowledge of statistical techniques useful in making rational decision in management problems and sampling distributions

REFERENCES:

1. Grewal, B.S., 2015. *Higher Engineering Mathematics*. Khanna Publishers.

2. Taha, H.A., 2002. *Operations Research: An Introduction.* Pearson Education Edition, Asia, New Delhi.

3. Jodhnson, R.A. and Gupta, C.N., 2007. *Miller and Freund's Probability and Statistics for Engineers and Scientists.* Pearson Education, Asia.

4. Jain. and Iyengar., 2007. *Advanced Engineering Mathematics*. Dorling Kindersley.

PE1133	INDUSTRIAL CHEMICAL PROCESS	L	T	P	C
		3	0	2	4

OBJECTIVES:

- To introduce history, importance and components of chemical engineering, concepts of unit operations and unit processes, and current scenario of chemical & allied process industries.

UNIT I HYDROCARBONS FROM PETROLEUM 9

Natural gas - Synthesis gas - Petroleum and petroleum products - Coal and coal products-Synthesis, properties and uses of Ethylene - Propylene - Butadiene - Vinyl chloride - Vinylidiene chloride - Vinyl fluoride - Vinylidene fluoride - Vinyl acetate.

UNIT II INDUSTRIAL ORGANIC SYNTHESIS 9

Synthesis and Manufacturing, properties and uses of - Formaldehyde - Epicholorohydrin - Ethylene oxide - Propylene oxide - Ethylene glycol, Propylene glycol – Phenols - Aniline-Bisphenol-A, Phthalic acid - Adipic acid - Maleic acid - Maleic anhydride - Phthalic anhydride-ξ-caprolactam, ξ-Caprolactone

UNIT III SYNTHESIS OF ORGANIC MONOMERS - II 9

Synthesis, Properties and uses of Styrene – Hexamethylene diamine - Urea - Acrylic acid - Methacrylic acid - Acrylonitrile - Methyl methacrylate – Tolulene diisocyanate (TDI) Hexamethylene diisocyanate (HMDI)- Diphenyl methane diisocyanate (MDI)- Pyrrole, Furan-Thiophene- benzimidazoles, Oxazoles.

UNIT IV PAINTS INDUSTRIES 9

Introduction – Classification of Paints - Constituents of paints – Characteristics of paint – Manufacture of Paint – Requirements of a good paint – Emulsion paints- Manufacture of Emulsion paint - Chemical action of Emulsion paints – Latex Paints – Luminescent Paints – Fire Retardant paints - Heat Resistant Paints – Methods of Applying Paint – Varnishes – Raw materials of varnishes – Enamels – Lacquers – solvents and thinners.

UNIT V SYNTHETIC FIBER INDUSTRIES 9

Introduction – Important requirements of fiber – difference between natural fibers and artificial fibers – Properties of synthetic fiber – methods of spinning – application of synthetic fibers – Rayon – Viscous Rayon – Acetate Rayon – Cuprammonium Rayon – Nylon 6 – Nylon 66 – Terylene or Dacron

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Demonstrate the different types of hydrocarbons from petroleum products.

CO2: Produce the industrial organic chemicals used in polymer industries.

CO3: Illustrate the synthesis of monomers from organic compounds.

CO4: Apply the manufacturing process in various kinds of paints.

CO5: Demonstrate the different types of synthetic fibres.

REFERENCES:

1. Sharma, B.K., 2000. *Industrial Chemistry*. GOEL Publishing House.

2. Rao, M.G. and Sittig, M., 1997. *Dryden's outlines of chemical technology*. East-West press.

3. George T. Austin, Shreve Chemical Process Industries, McGraw-Hill Professional.

PE1134 PACKAGING & DECORATION OF PLASTICS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To impart knowledge on introduction of packaging and materials used in packaging
- To equip with the knowledge on machinery in packaging
- To develop an understanding on decorations of plastics packages
- To provide exposure in rigid packaging
- To provide understanding of quality control and environmental consideration

UNIT I INTRODUCTION TO PACKAGING

Introduction to packaging: Definitions, need for packaging, properties and forms of packaging materials (wood, metal, glass, paper and plastics). Advantages and disadvantages of plastics packaging applications (foods and beverages, cosmetics and toiletries, medical products, shipping containers, drugs and pharmaceuticals). Selection criteria for packaging materials.

UNIT II CONVERSION PROCESS FOR PACKAGING MATERIALS 9

Processing Techniques of Single Layer and Multilayer Packaging : Lamination techniques wet lamination, dry lamination, thermal or heat lamination (fusion method), wax or hot melt lamination, extrusion lamination (melt lamination), coextrusion process [cast film coextrusion, blown film coextrusion, coextrusion coating, coextrusion lamination, cast sheet coextrusion], Shrink wrapping, Pallet & stretch wrapping

UNIT III DECORATIONS OF PLASTICS PACKAGES 9

Main printing processes such as letter press, flexography, lithography, Gravure, silk screen, ink jet printing, hot die stamping, and gold blocking, Factors affecting the choice of a printing process. Finishing Techniques such as Heat sealing, pressure sealing, adhesive sealing, solvent sealing, ultrasonic sealing etc.

UNIT IV PROCESSES FOR RIGID PACKAGING 9

Thermoformed, moulded and rigid packages, Thermoforming packages: Position & thermoforming & wrap forming, solid phase pressure forming, scrabbles, twin sheet & melt - to- mold thermoforming, skin packaging, Polystyrene & other foams systems cushioning, plastic pallets, drums , shipping containers.

UNIT V EVALUATION AND TESTING OF PLASTICS PACKAGES 9

General test methods, heavy duty packages, testing of blown moulded containers, laminates, stack load test, drop test, vibration test unusual test methods, testing of flexible plastic films,

Mechanical properties – Tensile properties, Impact properties, Burst strength, Stiffness, flex resistance, Co-efficient of friction, and shrinkage.

Optical Properties – Clarity,– Oxygen transmission, Water vapour transmission rate

– Migration, Environmental Consideration- Pollutants an outline – ChloroFluoro Carbon (CFC), Dioxin Life cycle assessment: A case study

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Explain fundamentals, types and uses of plastics as packaging materials

CO2: Describe the various processing methods involved in packaging technology

CO3: Summarize the different types of decoration of plastic

CO4: Demonstrate the processes for rigid packaging

CO5: knowledge on quality control test methods for packaging

REFERENCES:

1. Paine, F.A., 1967. *Fundamentals of Packaging Technology.* Blackie & Sons Publication.

2. Athalye, A.S., 1992. *Plastics in Packaging.,* Tata McGraw Hill, New Delhi.

4. Susan E.M., 2004. *Plastic Packaging.* Hanser Gardner Publication.

5. Susan E.M., 2010. *Plastics Packaging Properties, Processing, and Applications*. John Culter.

6. Barnetson., 1996. *Plastics Materials for Packaging.* Rapra Publications.

7. Susan E.M., 1997. *Understanding Plastics Packaging Technology.* John Culter.

8. Aaron, L. and Brody Kenneth., 1997. *Encyclopedia of Packaging Technology*. Wiley.

9. Athayle, A.S., 1999. *Handbook of Packaging Plastics*, Multi Tech publishing C.

10. Selke, S. E. M., Culter, J. D. and Hernandez, R. J., 2004. *Plastics Packaging: Properties, Processing, Applications and Regulations*, Carl Hanser Verlag, USA.

PE1135	ADVANCED MOULDING TECHNOLOGY	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To make the students to acquire knowledge in specialised injection moulding techniques
- To impart knowledge in Reaction injection moulding and Structural reaction injection moulding process
- To make the students to acquire knowledge in advanced blow moulding and extrusion process

UNIT I SPECIALIZED INJECTION MOULDING - I 9

Introduction - Two colour injection moulding process - Gas assisted Injection Moulding – Water assisted Injection molding- Basic processes and procedures - Moulding aspects -shrinkage and summary.

UNIT II SPECIALISED INJECTION MOULDING– II 9

Counter flow moulding, Multi-layer Moulding, Liquid Injection Moulding processes. Foam injection moulding-Structural foam moulding - Microinjection moulding - types and process details - Merits & demerits.

UNIT III ADVANCED BLOW MOULDING 9

Introduction - Classification of advanced Blow moulding processes - Double Wall Blow Moulding Technology - Versatility - Press Blow Moulding Process - Three dimensional Blow Moulding Process - Multi-layer Blow Moulding Process – merits & demerits.

UNIT IV REACTION INJECTION MOULDING 9

Reaction Injection Moulding (RIM) - raw materials-polyols and isocyanates Formulations, selection of process, process steps, advantages & disadvantages. Structural Reaction Injection Moulding (SRIM)- Reinforcements- Process Steps – Merits. Reaction transfer molding- Process Steps- advantages & disadvantages

UNIT V EXTRUSION PROCESS 9

Introduction - Extrusion of Multi-layer films, co-extruded sheets, Pipes & Corrugated pipes & profiles. - Material - Process - Process optimization - Cooling & applications.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Differentiate the working principles of Two colour Injection moulding, Gas assisted Injection Moulding and Water assisted Injection molding

CO2: Compare Microinjection molding, two colour injection moulding, multi-layer moulding and foam injection moulding process

CO3: Apply advanced blow molding principles to make polymer products

CO4: Apply reaction injection moulding principles to make polyurethane products

CO5: Apply the extrusion principles for making pipes, profiles, mulitlayer films & sheets

REFERENCES:

1. Kumar, A. and Gupta, R.K., 2018. *Fundamentals of polymer engineering*. CRC Press.

2. Agassant, J.F., Avenas, P., Carreau, P.J., Vergnes, B. and Vincent, M., 2017. *Polymer processing: principles and modeling*. Carl Hanser Verlag GmbH Co KG.

3. Baird, D.G. and Collias, D.I., 2014. *Polymer processing: principles and*

design. John Wiley & Sons.7.
4. Lafleur, P.G. and Vergnes, B. eds., 2014. *Polymer extrusion*. John Wiley & Sons.
5. Rosato, D.V. and Rosato, M.G., 2012. *Injection molding handbook*. Springer Science & Business Media.
6. Thomas, S. and Yang, W. eds., 2009. *Advances in polymer processing: from macro-to nano-scales*. Elsevier.
7. Tadmor, Z. and Gogos, C.G., 2013. *Principles of polymer processing*. John Wiley & Sons.
8. Crawford, R.J. and Martin, P.J., 2020. *Plastics engineering*. Butterworth-Heinemann.
9. Cheremisinoff, N.P. and Cheremisinoff, P.N., 1996. *Handbook of applied polymer processing technology* (Vol. 31). CRC Press.

PE1136 ADVANCED POLYMER SYNTHESIS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To impart knowledge about significance of stereochemistry in polymer synthesis, and its application in commercial polymer manufacture.
- To impart various advanced polymerization mechanisms.
- To create sound understanding of polymer reactions, and, thereby, polymer modifications

UNIT I STEREOCHEMISTRY OF POLYMERIZATION 9

Types of Stereoisomerism in Polymers – Mono- and disubstituted Ethylenes, Carbonyl, Butadiene and substituted butadienes, etc. Properties of Stereoregular Polymers. Stereoregulation in Alkene Polymerizations. Ziegler-Natta and Metallocene Polymerization mechanisms. Commercial applications of stereoregular polymerization.

UNIT II RING-OPENING POLYMERIZATION (ROP) 9

General Characteristics, Scope, Polymerizability,Polymerization Mechanism and Kinetics. Anionic and cationic polymerization of Cyclic Ethers, Lactams, Lactones, Heterocyclics, Copolymerization.

UNIT III ADVANCED POLYMERIZATION MECHANISMS 9

Metathesis polymerization, Atom transfer radial polymerization (ATRP), Reversible-fragmentation chain transfer polymerization (RAFT), Clickpolymerization, Phase transfer polymerization, Group transfer polymerization

UNIT IV REACTIONS OF POLYMERS 9

Principles of Polymer Reactivity – Yield, Isolation of Functional Groups,Concentration, Crystallinity, Change in Solubility, Crosslinking, Steric Effects, Electrostatic Effects,Neighboring-Group Effects, Hydrophobic Interactions , etc. Crosslinking – Alkyds, Elastomers basedon 1,3-Dienes, Sulfur and Accelerated Sulfur Vulcanization, Other Vulcanizations, Peroxide andRadiation Crosslinking, Other Crosslinking Processes. Reactions of Polysaccharides (Cellulose,starch, etc.), Poly(vinyl acetate). Halogenation of Natural Rubber, Saturated Hydrocarbon Polymers.Aromatic Substitution. Cyclization. Other Reactions. Radical and Ionic graft copolymers. BlockCopolymers.

UNIT V MODIFICATION OF POLYMERS **9**

Overview of polymer modification reactions such as Hydrolysis, Acidolysis, Aminolysis, Hydrogenation, Addition and Substitution, etc. Specific group reactions such as Hydroxyl, Aldehyde, Ketone, Carboxyl, Amino, etc

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Predict the structure of Stereoisomerism in polymers
CO2: Determine the polymers for the ring opening polymerization
CO3: Explain the advanced polymerization mechanisms
CO4: Demonstrate the reaction in polymers using crosslink agent
CO5: modify the polymers structure by chemical reactions

REFERENCES:

1. Odian, G., 2004. *Principles of polymerization*. John Wiley & Sons.
2. Mark, H.F., 2013. *Encyclopedia of polymer science and technology, concise*. John Wiley & Sons.
3. Barner-Kowollik, C. ed., 2008. *Handbook of RAFT polymerization*. John Wiley & Sons.

PE1137 **REACTION ENGINEERING**

L	T	P	C
3	0	2	4

OBJECTIVES:

- To train students in Polymerization reaction kinetics and evaluation of reaction rate and reactors.
- To make the student conversant with the reaction control and reactor stability
- To familiarize chemical equilibria and equilibrium constant to students

UNIT I POLYMERIZATON MECHANISM AND KINETICS **9**

Introduction to Polymerization reactors - Free-Radical Polymerization – Addition Polymerization – condensation polymerization – copolymerization - mechanisms and kinetics.

UNIT II REACTOR TYPES 9

Batch reactors – Semi batch (semicontinuous) reactors - Continuous stirred-tank reactors - Tubular reactors - Gas phase reactor system

UNIT III CHEMICAL EQUILIBRIA AND EQUILIBRIUM CONSTANT 9

Reaction equilibria – equilibrium in chemically reactive system – evaluation of equilibrium constant – effects of temperature on equilibrium – equilibrium composition evaluation.

UNIT IV REACTOR STABILITY AND CONTROL OF REACTION RATES 9

Reactor stability – criteria for stability of reactors, limit cycles and oscillating reactions -Classical polymerization reaction control problems- Control of reaction rates and of reactor temperature.

UNIT V POLYMERIZATON REACTION CONTROL 9

Control of Polymerization Reactors - Control of monomer conversion and polymer production - Control of molecular weight averages and MWDs - Control of copolymer composition - Control of particle size and PSDs.

TOTAL: 45+30=75 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to apply he

CO1. apply the knowledge of polymerization mechanism and its kinetics

CO2. Identify a reactor for polymer production

CO3. Explain the Chemical equilibria and equilibrium constant of polymerization reactions

CO4. Evaluate the reactor stability and control of reaction rates

CO5. Control the polymerization reaction for molecular weight averages.

REFERENCES:

1. Meyer, T. and Keurentjes, J.T., 2005. *Handbook of polymer reaction engineering*. Wiley-VCH Verlag.

2. Kumar, A. and Gupta, R.K., 2018. *Fundamentals of polymer engineering*. CRC Press.

3. Mishra, M. and Yagci, Y., 1998. *Handbook of radical vinyl polymerization* (Vol. 73). CRC Press.

4. James, J.C., 1989. *Process modeling, simulation and control for chemical engineers*. McGraw-Hill.

5. Levenspiel, O., 2014. *Engineering flow and heat exchange*. Springer.

PE1138 RESEARCH METHODOLOGY

L	T	P	C
3	0	0	3

OBJECTIVES:

- To gain insights into how scientific research is conducted.
- To help in critical review of literature and assessing the research trends, quality and extension potential of research and equip students to undertake research.
- To learn and understand the basic statistics involved in data presentation.
- To identify the influencing factor or determinants of research parameters.

UNIT I OBJECTIVES AND TYPES OF RESEARCH 9

Motivation and objectives – Research methods vs Methodology. Types of research with examples – Descriptive vs. Analytical, Applied vs. Fundamental, Quantitative vs. Qualitative, Conceptual vs. Empirical. Literature survey tools/ search engines .

UNIT II RESEARCH FORMULATION 9

Research design – Basic Principles- Need of research design –– Features of good design – Important concepts relating to research design – Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction, Development of Models. Developing a research plan - Exploration, Description, Diagnosis, and Experimentation. Determining experimental and sample designs.

UNIT III RESEARCH DESIGN AND METHODS 9

Research design – Basic Principles- Need of research design –– Features of good design – Important concepts relating to research design – Observation and Facts, Laws and Theories, Prediction and explanation, Induction, Deduction, Development of Models. Developing a research plan - Exploration, Description, Diagnosis, and Experimentation. Determining experimental and sample designs .

UNIT IV DATA COLLECTION AND ANALYSIS 9

Execution of the research - Observation and Collection of data - Methods of data collection – Sampling Methods- Data Processing and Analysis strategies - Data Analysis with Statistical Packages - Hypothesis-testing - Generalization and Interpretation .

UNIT V REPORTING AND THESIS WRITING 9

Structure and components of scientific reports - Types of report – Technical reports and thesis – Significance – Different steps in the preparation – Layout, structure and Language of typical reports – Illustrations and tables - Bibliography, referencing and footnotes - Oral presentation – Planning -Preparation –Practice – Making presentation – Use of visual aids - Importance of effective communication. Application of results and ethics -– Reproduction of published material, Plagiarism - Citation and acknowledgement - Reproducibility and accountability

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Develop hypothesis and methodology for research
CO2: Formulate the research problem
CO3: Develop the research design
CO4: Execute the research data collection
CO5: Demonstrate the thesis writing and reporting

REFERENCES:

1. Kothari, C.R., 2004. *Research methodology: Methods and techniques*. New Age International.
2. Garg, B.L., Karadia, R., and Agarwal, 2002. *An introduction to Research Methodology, RBSA Publishers*, U.K.,
3. Sinha, S.C. and Dhiman, A.K., 2002. Research Methodology (Vol. 1). *New Delhi: Ess Ess*.
4. Trochim, W., 2005. Research Methods: The Concise Knowledge Base. Cincinnatti, OH.
5. Graziano, A.M. and Raulin, M.L., 1993. *Research methods: A process of inquiry*. HarperCollins College Publishers.
6. Fink, A., 2019. *Conducting research literature reviews: From the internet to paper*. Sage publications.

PE1231	ADDITIVE MANUFACTURING	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To Understand fundamentals of Additive manufacturing technology
- To describe reverse engineering and CAD modeling
- To analyze various additive manufacturing systems

UNIT I INTRODUCTION 9

Need - Development of AM systems – AM process chain - Impact of AM on Product Development - Virtual Prototyping- Rapid Tooling – RP to AM -Classification of AM processes-Benefits Applications.

UNIT II REVERSE ENGINEERING AND CAD MODELING 9

Basic concept- Digitization techniques – Model reconstruction – Data Processing for Rapid Prototyping: CAD model preparation, Data requirements – Geometric modeling techniques: Wire frame, surface and solid modeling – data formats - Data interfacing, Part orientation and support generation, Support structure design, Model Slicing, Tool path generation-Software for AM- Case studies.

UNIT III LIQUID BASED AND SOLID BASED ADDITIVE MANUFACTURING SYSTEMS 9

Stereolithography Apparatus (SLA): Principle, pre-build process, part-building and post-build processes, photo polymerization of SL resins, part quality and process planning, recoating issues, materials, advantages, limitations and applications. Solid Ground Curing (SGC): working principle, process, strengths, weaknesses and applications. Fused deposition Modeling (FDM): Principle, details of processes, process variables, types, products, materials and applications. Laminated Object Manufacturing (LOM): Working Principles, details of processes, products, materials, advantages, limitations and applications - Case studies.

UNIT IV POWDER BASED ADDITIVE MANUFACTURING SYSTEMS 9

Selective Laser Sintering (SLS): Principle, process, Indirect and direct SLS- powder structures, materials, post processing, surface deviation and accuracy, Applications. Laser Engineered Net Shaping (LENS): Processes, materials, products, advantages, limitations and applications– Case Studies.

UNIT V TOOLING 9

Classification, Soft tooling, Production tooling, Bridge tooling, direct and indirect tooling, Fabrication processes, Applications Case studies automotive, aerospace and electronics industries

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Express history, concepts and terminology of additive manufacturing
CO2: Apply the reverse engineering concepts for design development
CO3: Select the variety of additive manufacturing techniques
CO4: Design and develop newer tooling models
CO5: Analyze the cases relevant to mass customization and some of the important research challenges associated with AM and its data processing tools

REFERENCES:

1. Chua, C.K., Leong, K.F. and Lim, C.S., 2010. *Rapid prototyping: principles and applications (with companion CD-ROM)*. World Scientific Publishing Company.
2. Hanser Gebhardt, A., 2003. *Rapid Prototyping*. Hanser Gardener Publications Gibson, I., Rosen, D.W. and Stucker, B., 2010. Design for additive manufacturing. In *Additive manufacturing technologies* (pp. 299-332). Springer, Boston, MA.
3. Hilton, P., 2000. *Rapid tooling: technologies and industrial applications*. CRC press.
4. Kamrani, A.K. and Nasr, E.A. eds., 2006. *Rapid prototyping: theory and practice* (Vol. 6). Springer Science & Business Media.
5. Liou, F.W., 2007. *Rapid prototyping and engineering applications: a toolbox for prototype development*. Crc Press.

PE1232 CHARACTERIZATION OF MACROMOLECULES

L	T	P	C
3	0	0	3

OBJECTIVES:

- To provide the student with an understanding of the microscopy technique
- To understand the importance of spectroscopy techniques.
- To equip with the knowledge of thermal and separation of polymers.
- To familiarize the student with the common methods used in the analytical characterization of polymers
- To impart the knowledge of rheological characterization.

UNIT I MICROSCOPY

Light microscopy - Electron microscopy – TEM, SEM, AFM, Principle, Instrument, Specimen preparations, applications. Analytical electron microscopy (AEM), X-ray energy spectroscopy (XES). Electron scanning chemical analysis (ESCA).

UNIT II SPECTROSCOPY 9

Ultra-violet/Visible spectroscopy - Introduction, principle, Lambert law, Beer's law, theory, instrumentation, procedure, advantages, disadvantages, interpretation of spectrogram, applications

Fourier transformer infrared (FTIR) spectroscopy - Introduction, principle, theory, instrumentation, procedure, methods of sample preparation, advantages, disadvantages, interpretation of spectrogram, and applications

Nuclear Magnetic spectroscopy (NMR)- (1H NMR and 13C NMR) - Introduction Principle, theory, Spin-spin coupling, instrumentation, procedure, method of sample preparation, advantages, disadvantages, applications

UNIT III SEPARATION TECHNIQUES AND X-RAY DIFFRACTION 9

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

UNIT IV THERMAL METHODS 9

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

UNIT V RHEOLOGICAL CHARACTERIZATION 9

Introduction and definitions related to fluid flow - Newtonian and non-Newtonian and visco elastic fluids. Rheological properties - viscosity, melt-flow, relationships

describing temperature and shear rate dependence on the rheological behaviour of amorphous and crystalline plastics materials, Viscosity measurements - capillary rheometer, viscometer, torque rheometers, cup flow and spiral flow tests for determination of flow behaviour.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Analyze and interpret the data taken by microscopy characterization methods

CO2: Predict both qualitative and quantitative basis on the structure, properties and composition of a polymer by spectroscopy methods

CO3: Determine the molecular weight and its distribution by various methods.

CO4: Predict the thermal properties of polymers by instrumental techniques. Interpret the test results.

CO5: Examine the flow behavior of polymer

REFERENCES:

1. T.R. Crompton, T.R., 2008. *Characterization of Polymers*. Smithers Rapra technology limited.

2. Campbell. and White, J. R., 2017. *Polymer Characterization Physical Techniques*. Chapman and Hall, London.

3. Spells, J., 1994. *Characterization of Solid Polymers*. Chapman and Hall, London.

4. Rohn, C.L., 1995. *Analytical Polymer Rheology*. Hanser Publishers, Munich.

5. Turi, E.A., 2012. *Thermal Characterization of Polymeric Materials.* Academic Press, New York.

PE1233	FIBER SCIENCE AND TECHNOLOGY	L	T	P	C
		3	0	0	3

OBJECTIVES:

To enable the students to learn the

- To impart knowledge on Production technologies of synthetic fibres such as nylon6, PET, PP and acrylic fibres
- To make the students to acquire knowledge on concepts of Melt spinning, wet spinning, dry spinning, texturing and stretching methods; colouration techniques of fibres.
- To provide the basic Modification process for low filling, flame retardant and hollow fibres

UNIT I RAW MATERIALS 9

Development of synthetic - commercial synthetic fibres, Raw materials manufacture. DMT, TPA, MEG, caprolactum, adipic acid, hexamethylene diamine, acrylonitrile, polymerisation - types of polymers - criteria for fibre forming polymers - production of polyethylene terephthalate polymer - polyamides - production of nylon 66 polymer - nylon 6 polymer

UNIT II MANUFACTURING OF FIBER FORMING POLYMERS 9

Polymer production for acrylic fibres - polypropylene - production of other fibres – PVC fibres - PVA fibres - Aramid fibres - Melt spinning - Polymer feed - melt spinning equipment - high speed spinning - spin draw processes - crystallization method – melt spinning of PET & PP stable fibres - wet and dry spinning comparison. Spin finishes -functions of spin finish - methods of application of spin finish - spin finish for polyester staple fibres - spin finish for texturing process - effect of spin finish on dyeing

UNIT III STRETCHING AND DYEING 9

Stretching or drawing - conditions of drawing - machines for draw warping - texturing - false twist process - draw texturing- staple fibre production, melt spinning - drawing, heat setting - crimping in fibre line - production of melt spin staple fibre - polyester tops for wool blending - Mass coloration and tow dyeing of polyester, nylon, acrylic - polypropylene - dyeing in loose fibre and yarn forms of polyester, nylon, acrylic, PP, other synthetic fibres - loose fibre dyeing

UNIT IV MODIFIED SYNTHETIC FIBERS 9

Modified synthetic fibres - modified polyester, Nylon, PP, acrylics - Hydrophilic - Hollow - Low pilling - flame retardant- bicomponent fibres - Dyeability of synthetic fibres

UNIT V TESTING AND WASTE UTILIZATION 9

Quality control - testing raw material - testing polymers - testing yarns & fibres – waste utilisation of polyester - nylon 6 - 66 - acrylics - PP- Energy conservation – pollution control.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Apply the knowledge on selection of raw materials for fiber forming polymers

CO2: Demonstrate the manufacturing processing techniques for different fibres.

CO3: Apply the knowledge on stretching and dyeing process for synthetic fibers

CO4: Modify the properties of various synthetic fibers for end applications
CO5: Demonstrate the testing procedure and waste utilization of indusial fibers

REFERENCES:

1.Vaidya, A.A, 1988, *Production of synthetic fibres*, Prentice Hall of India Pvt. Ltd, New Delhi.
2. McIntyre, J E, 2005,*Synthetic Fibres: Nylon, Polyester, Acrylic, Polyolefin*, Elsevier Science.
3. Fourne, Franz, 1999, *Synthetic Fibres, Machines and Equipment, Manufacture, Properties*, Hanser Publishes.
4. Corbman Bernard, 1983, *Textiles: fibre to fabric*, Sixth Edition, McGraw Hill,

PE1234 INDUSTRIAL MANAGEMENT

L	T	P	C
3	0	0	3

OBJECTIVES:

- To acquire knowledge on industrial management and productivity.
- To make the students to learn the Industrial relations, leadership and management in the trade union.
- To understand the basic concepts of inspection, quality control and work study

UNIT I INTRODUCTION TO INDUSTRIAL MANAGEMENT AND PRODUCTIVITY 9

Concepts of Industrial Engineering – History and development – Role of Industrial Engineers – Applications- production Management, Production Management Vs Industrial Management – Operations Management
Productivity – function, system, factors affecting productivity, increasing productivity of resource, kinds of productivity measures

UNIT II PLANT LOCATION, PRODUCT DESIGN AND PLANNING 9

Concepts and factors governing plant location – plant-product-process layout – plant layout procedure – introduction to product design – effect of design of cost-product planning – classification –development – standardization –simplification-specialization –Diversification.

UNIT III INSPECTION, QUALITY CONTROL AND WORK STUDY 9

Objectives of inspection –kind of inspection – statistical process control – Poisson's distribution – normal distribution – distribution pattern – control charts and their applications- the Zero Defect concepts.
Work Study: Needs-advantages-objectives –Method study-flow process- flow diagram-Analysis of motion- SIMO chart-M-T measurement –work measurement techniques.

UNIT IV MAN POWER PLANNING **9**

Need – objectives – planning for future – manpower planning process- projecting manpower supply and demand at organizational level – developing manpower strategy - recruitment selection and induction – process of recruitment – selection tests – placement induction – orientation – training and development – training – management development – retraining – evaluation of training programme

UNIT V UNION AND INDUSTRIAL RELATIONSHIP **9**

trade unions - Industrial disputes - collective bargaining – types of bargaining – new collective bargaining –negotiation skills – trends in collective bargaining- workers participation and management - Concept, strategies and practices

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Apply the industrial management concepts in industries

CO2: demonstrate the product planning process

CO3: select the process control tool for quality control process

CO4: utilize the manpower in an effective manner

CO5: Apply the negotiation and collective bargaining techniques in industrial sectors.

REFERENCES:

1. Memoria, C.B. and Memoria, S. 1985, *Dynamics of Industrial Relations in India*, Himalaya
Publishing co., Bombay.

2. Memoria, C.B. 1985, *Personnel Management*, Himalaya Publishing Co., Bombay.

3. Lucas Jr, H.C. 1978, *Information System Concepts for Management*, McGraw Hill, Kogakusha.

4. Robbins, 1982, *The Management of Human Resource*, Prentics, Hall, New Jersey.

PE1235	COMPUTER AIDED DESIGN MOULD & DIE MANUFACTURING	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To impart knowledge on Computer aided design for molds and dies
- To make the students to acquire knowledge in NC Part programming and Computer Numerical Control.
- To provide exposure in metrology and inspection

UNIT I COMPUTER AIDED DESIGN 9

Introduction to molds and dies- Design process- sequential and concurrent engineering- Computer aided design – CAD system architecture- Computer graphics – co-ordinate systems- 2D and 3D transformations- homogeneous coordinates – Line drawing -Clipping- viewing transformation

UNIT II NC PART PROGRAMMING 9

Introduction of Part Programming, types – Detailed Manual part programming on Lathe & Milling machines using G codes and M codes- Cutting Cycles, Loops, Sub program and Macros- Introduction of CAM package.

UNIT III COMPUTER NUMERICAL CONTROL 9

Introduction to NC systems and CNC – Machine axis and Co-ordinate system- CNC machine tools-Principle of operation CNC- Construction features including structure-Drives and CNC controllers-2D and 3D machining on CNC

UNIT IV ELECTRICAL DISCHARGE MECHINING 9

Electrical discharge machining – Principle, Types of EDM – CNC Die Sinking & CNC Wire Cut EDM, Machining Process, Requirements of dielectric fluid, Applications of EDM in mold making.

UNIT V METROLOGY AND INSPECTION 9

Metrology and inspection: Vernier caliper, Micrometer, Mechanical comparators, Optical Comparators, Electrical comparators, Surface plate, Slip gauges, Sine Bar, Optical profile projectors, Optical flat & CMM.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Apply the computer aided design principles for molds and dies

CO2: Apply NC codes to prepare machining program.

CO3: Utilize CNC Program for various machining process

CO4: demonstrate the principle and applications of CNC EDM in mold making

CO5: Measure the dimensions of mold using basic measuring instruments

REFERENCES:

1.Grover, M.P. and Zimmers, E.W., 2006. *CAD/CAM Computer-Aided Design and Manufacturing*. Pearson Education.

2.Donaldson, C., LeCain, G.H., Goold, V.C. and Ghose, J., 2012. *Tool design*. Tata McGraw-Hill Education.

3.Bi, Z. and Wang, X., 2020. *Computer Aided Design and Manufacturing*. John Wiley & Sons.

4.Sarcar, M.M.M., Rao, K.M. and Narayan, K.L., 2008. *Computer aided design and manufacturing*. PHI Learning Pvt. Ltd..

PE1236	INTELLECTUAL PROPERTY RIGHTS AND COPY RIGHT LAWS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To impart intellectual properties, patents, trade marks and design rights
- To provide the procedure for applying patent documentation
- To get information on the industrial design and its projection
- To learn about the procedure for commercialization of intellectual properties

UNIT I TYPES OF PROPERTY 9

Introduction – Invention and Creativity – Intellectual Property (IP) – Importance – Protection of IPR – Basic types of property (i). Movable Property - Immovable Property and - Intellectual Property.

UNIT II PATENTS 9

IP – Patents – Copyrights and related rights – Trade Marks and rights arising fromTrademark registration – Definitions – Industrial Designs and Integrated circuits –Protection of Geographical Indications at national and International levels – Application Procedures.

UNIT III INTELLECTUAL PROPERTY 9

International convention relating to Intellectual Property – Establishment of WIPO – Mission and Activities – History – General Agreement on Trade and Tariff (GATT) – TRIPS Agreement.

UNIT IV IPR 9

Indian Position Vs WTO and Strategies – Indian IPR legislations – commitments to WTO-Patent Ordinance and the Bill – Draft of a national Intellectual Property Policy – Present against unfair competition.

UNIT V CASE STUDIES 9

Case Studies on – Patents (Basmati rice, turmeric, Neem, etc.) – Copyright and related rights – Trade Marks – Industrial design and Integrated circuits – Geographic indications – Protection against unfair competition

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Explain the types of property
CO2: Relate and distinquish the patents and copyrights
CO3: Correlate the International convention relating to Intellectual Property
CO4: State the Indian IPR strategies
CO5: Express the patents and copyrights case studies

REFERENCES:

1. Whitney, E., United States Patent Number: 72X. *Cotton Gin, March*, *14*, p.1794.

Today, I.P., Volume 8, No. 5, May 2001.
2.Subbaram, N.R., 1998. *Handbook of Indian Patent Law and Practice*. S Viswanathan.
3.Using the Internet for non-patent prior art searches, Derwent IP Matters, July 2000
4.www.ipmatters.net/features/000707_gibbs.html.

PE1237 POLYMER DEGRADATION AND STABILIZATION

L	T	P	C
3	0	0	3

OBJECTIVES:

- To familiarize with the usage of importance of polymer degradation
- To learn about the reactions of degradation of polymers

UNIT I CONCEPT OF DEGRADATION PROCESS 9

Definition - Modes of Polymer Degradation - Mechanistic Aspects - Single Step Process and Chain Reactions - Auto Oxidation - Random and Specific Site Attack - The practical significance of polymer degradation, Polymer durability - Polymer stabilization - Recycling of polymers - Degradable polymers - Advantages and disadvantages of polymer degradation – general factors of polymer degradation

UNIT II ANTIOXIDANTS AND STABILIZERS 9

Antioxidants and stabilizers - Mechanism of antioxidant action, chain breaking antioxidants, preventive antioxidants, synergism and antagonism, chain breakingacceptor antioxidants, metal deactivators, UV screens and filters, stabilization of polymers during manufacture and in service, melt stabilization, thermal oxidative stabilization, polymer bound antioxidants, and UV stabilizers.

UNIT III PHOTO DEGRADATION 9

Photo degradation: Introduction - Mechanistic Aspects (Excited States, Free Radicals and Ionic Species, Energy Transfer and Energy Migration) - Degradation in the Absence of Oxygen (Norrish Types I & II Reactions) - Photo Oxidation (Auto Oxidative Process, Sensitized Degradation) - Stabilization - Application: Polymers with Predictable Life Time, Photo resists

UNIT IV BIODEGRADATION 9

Biodegradation:Introduction - Aspects of Radiation - Mechanistic Aspects - Simultaneous Cross Linking and Degradation - Modes of Biological Degradation - Enzymatic Degradation in Bio Polymers (Polysaccharides, Proteins, Malice Acids) - Microbial Degradation of Synthetic Polymers - General Applications of Bio Degradable Plastics - Examples of Biodegradable Polyesters and Polyamides.

UNIT V CHEMICAL DEGRADATION 9

Chemical Degradation: Introduction - Solvolysis - Polymer Characterization by Solvolysis - Stability of Polymer Against Solvolytic Agents - Commercial Applications - Ozonisation - Oxidative Degradation - Auto Oxidation of Polymers. Ionic

Degradation: Alkaline Degradation of Poly Saccharides Acidic Degradation of Polyaldehydes and Polyacetals and Cationic Degradation of Polypropylene Sulphide and Polyesters.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Demonstrate the fundamental aspects of polymer degradation

CO2: Select different stabilizers, antioxidants and fire retardants used in polymer degradation

CO3: Apply the photo degradation and their mechanism.

CO4: Apply the Biodegradation mechanism in Synthetic Polymers

CO5: Implement Chemical Degradation process in oxidation of polymers.

REFERENCES:

1.Albertsson, A.C. and Huang, S.J. eds., 1995. *Degradable polymers, recycling, and plastics waste management*. M. Dekker.

2.Ehrenstein G.W., Riedel G., Trawiel P., (2004) *Thermal analysis of plastics*, Hanser.

3.Hamid S.H., Amin M.B., (1992) *Handbook of Polymer Degradation*, Marcel Dekker.

4.W. Schnabel, (1992) *Polymer Degradation - Principles and Practical Applications* Hanser Publishers, New York.

PE1238 SPECIALITY AND FUNCTIONAL POLYMERS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To make the student acquire knowledge on liquid crystalline polymers.
- To provide exposure on conducting and piezoelectric polymers.
- To impart a thorough understanding of heat resistant polymers.
- To provide knowledge on photosensitive and photoresist polymers.
- To facilitate the students to understand the use of polymers for specialty applications.

UNIT I LIQUID CRYSTALLINE POLYMERS 9

Liquid crystal polymers: Smectic, nematic, cholesteric crystals, theromotropic main chain liquid crystal polymers, side chain liquid crystal polymers, chiral nematic liquid crystal polymers, properties of Commercial LCPs. Concept of liquid crystalline (LC) phase, liquid crystalline polymers and their classification -theories of liquid crystallinity, characteristics of LC state and LCPs, synthesis, structure property relationship, rheology of liquid crystalline polymers, blends of LCPs, self-reinforced composites, applications of LCPs

UNIT II CONDUCTING POLYMERS 9

Conducting polymers -Theory of conduction, semi conductors and band theory, requirements for polymer to work as conductor, types of conducting polymers - intrinsic and extrinsic, doping of polymeric systems, Mechanism of conducting polymers- Polyaniline, Polyacetylene, Polypyrole, organometallic 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, applications of heat resistant polymers like polyamides, polyimides and its derivatives, polyquinolines, polyquinoxalines, Polymers for high temperature resistant applications - PBO, PBI, PPS, PPO, PEEK and Fluro polymers.

UNIT IV PHOTOSENSITIVEAND PHOTORESIST POLYMERS 9

Photosensitive polymers – synthesis - curing reactions - applications in various fields. Photo resist for semiconductor fabrication. Membranes – types - methods of casting - applications. Polymers in photo-resist applications, negative photoresists, positive photoresists, plasma developable photoresists, photoresists applications for printing, polymers in Fiber optics, polymers in Nonlinear optics.

UNIT V POLYMERS IN 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, polymeric materials used in telecommunication and power transmission applications, polymer composites in aerospace and other light weight applications, polymers in cosmetics.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Express the importance of rheology of liquid crystalline polymers

CO2. state the importance of Polymeric doping systems

CO3. Apply the knowledge on the use of polymers for high temperature applications

CO4. Identify the application of photoresists and photosensitivepolymers.

CO5. Apply the polymers for agricultural, aerospace and telecommunications

REFERENCES:

1.Chanda, M. and Roy, S.K., 2008. *Industrial polymers, specialty polymers, and their applications* (Vol. 74). CRC press.

2. Mohammad, F. ed., 2007. *Specialty polymers: materials and applications*. IK International Pvt Ltd.

3. Dyson, R.W., 1991. *Engineering polymers*. Springer Science & Business Media.

4. Dyson R.W. (eds)., 1987. *Specialty Polymers.* Springer, Boston, MA. ©

Blackie & Son Ltd.
5. Manas Chanda, Salil K.Roy, 2nd edition,1993. *Plastics Technology Hand book* Marcel Dekker Inc, New York.
6. Johannes Karl Fink,Vol .2, 2011. *Hand book of Engineering and Specialty Polymers*, John Wiley & Sons.
7. Norio Ise, IwaoTabushi, 1983,*An Introduction to Speciality Polymers*, Cambridge University Press.
8. Johannes Karl Fink, 2nd edition ,2014, *High Performance Polymers*, Elsevier Inc,
9. V. Shibaev, Liquid Crystalline Polymers, S. Hashmi (Ed.), 2016, *Reference Module in Materials Science and Materials Engineering*. Elsevier.

PE1331 ADHESIVES SCIENCE AND SEALANTS TECHNOLOGY

L	T	P	C
3	0	0	3

OBJECTIVES:

- To bring a sound knowledge of theoretical and technological aspects of mechanism of adhesives.
- To understand the various types of Adhesives employed in Industries and its formulation.
- To acquire knowledge of testing of adhesive bonding in various fields.
- To impart a basic understanding of Sealant classification, composition and its families.
- To get a knowledge of selection and using of sealants

UNIT I THEORY AND MECHANISM OF ADHESION 9

Introduction & classification of adhesives, mechanism of adhesion of polymeric coatings on various substrates. Theories of adhesion, mechanical interlocking theory, diffusion, electrostatic, adsorption, chemisorptions, surface energetics and wettability, guidelines for good adhesion, advantages &disadvantages of using adhesive bonding over conventional joining techniques.

UNIT II ADHESIVE FORMULATIONS AND ITS TYPES 9

Principle of adhesives formulation and production techniques- adhesives formulation for various industries viz. construction-packaging, textiles, automotive, consumer, abrasives and friction material shoes, electrical, aerospace, etc. Types of adhesives: structural adhesives, epoxy, acrylic, phenolic, elastomeric modified adhesive, PU adhesives, natural product such as starch, dextrin, cellulose ether, cellulose ester, natural gum resins based adhesives, pressure sensitive adhesives, hot melt adhesives, solvent & emulsion based adhesives, health and safety.

UNIT III TESTING OF ADHESIVES 9

Surface characterization, surface preparation and treatments for various substrates, techniques for evaluation of adhesives, mechanical testing of adhesive bonding,

chemistry and uses of adhesives, surface characteristics of various substrates, various types of joints used in adhesion bonding, manufacture of adhesives, properties and testing of adhesives. (as per ASTM standards), Need of testing adhesives,viscosity, pot life , tack,cure rate, percent solids, Joint test: Shear, tensile, peel , impact, strength retention and non destructive testing.

UNIT IV SEALANT CLASSIFICATION, COMPOSITION AND ITS FAMILIES 9

Introduction-classification-composition–formulation-Primary resin – Solvents- Fillers - Plasticizers - Additives to improve adhesion - Other additives-Sealant formulation-Application properties - Performance properties-commercial products and formulation. Sealant families-Low-Oil- and resin-based sealants- Asphaltic and other bitumenous mastics - Polyvinyl acetate, medium-Hydrocarbon rubber-based sealants - Acrylic - Chlorosulfonated polyethylene (Hypalon)- Hot-melt sealants and high performance sealants-Polyurethane- Silicone - Styrene butadiene copolymer sealants- Chloroprenes- specialty sealants.

UNIT V SELECTION OF SEALANTS 9

Introduction-nature of joint design-Common butt and lap joints- Backup materials-Threaded joints - Gasketing - Porosity sealing-Sealant substrates-Surface preparation – Primers- Common substrate surfaces - Concrete and masonry- Stone-Glass and porcelain- Painted surfaces- Unpainted metal-Application requirements - Bulk materials - Tape sealants - Preformed gaskets - Foam sealants - Application properties - Rheological properties - Ambient temperature on application - Cure rate and performance requirements-Movement capability - Other mechanical properties - Adhesion – Durability and Appearance.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Express the knowledge of theory and mechanism of adhesion.

CO2. Apply the formulation of adhesives in industry.

CO3. Develop the test for bonding of adhesives in various fields

CO4. Apply the knowledge on Sealant classification, composition and its families

CO5. Demonstrate the selection of sealants to various applications

REFERENCES:

1.Ebnesajjad, S., 2011. *Handbook of adhesives and surface preparation: technology, applications and manufacturing*. William Andrew.

2.Cognard, P., 2005. *Handbook of adhesives and sealants: basic concepts and high tech bonding*. Elsevier.

3.Ghosh, P., 2008. *Adhesive and coating technology*. Tata McGraw-Hill Education.

4.Da Silva, L.F., Öchsner, A. and Adams, R.D. eds., 2011. *Handbook of adhesion technology*. Springer Science & Business Media.

5.Wake, W.C., 1982. *Adhesion and the Formulation of Adhesives*. Applied Science Publishers.
6.Cognard, P., 2005. *Handbook of adhesives and sealant.svol.1: basic concepts and high tech bonding*. Elsevier.
7.Cognard, P., 2006. *Handbook of adhesives and sealants.vol.2: general knowledge, application of adhesives, new curing techniques*. Elsevier.
8.Brinson, H.F., Dostal, C.A., Woods, M.S., Ronke, A.W., Henry, S.D., Daquila, J.L. and O'Keefe, K.L., 1990. *Engineered Materials Handbook Volume 3 Adhesives and Sealants. ASM International,* pp.33-38.
9.Petrie, E.M., 2006. Chapter 2: *Theories of adhesion. Handbook of adhesives and sealants,* 2nd edn. McGraw-Hill.

PE1332 POLYMER MULTIPHASE SYSTEM

L	T	P	C
3	0	0	3

OBJECTIVES:

- To impart the knowledge of polymer blends
- To impart understanding of thermodynamic aspects, phase diagram and morphology of polymer blends
- To impart the knowledge of various methods of compatibilization and toughening of polymer blend
- To impart understanding the rheology of blends

UNIT I INTRODUCTION TO POLYMER BLENDS

Fundamentals of Polymer Blends: Historical outline of industrial development of polymer blends and alloys, reasons for blending, definitions of terms used in polymer blends & alloys. Types of Polymer blends; blend components' selection criteria, methods of blending, fundamental principles for development of polymer alloys and blends; Designing a polymer blend.

Blending equipments: Mixers' and their types, like- banbury, hot and cold mixers, twin screw compounders, two-roll mills, etc. Design features of these equipments like rotor types, screws and their various types; flow behavior of the plastic material in the mixing equipments, theory of mixing.

UNIT II THERMODYNAMIC ASPECTS, AND MORPHOLOGY OF POLYMER BLENDS 9

Thermodynamic aspects of blending: combinatorial entropy of mixing, enthalpy of mixing, general principles of phase equilibria calculation, LCST and UCST concepts, theories of liquid mixtures containing polymer: Huggins-Flory theory, equation of state theories, Gas lattice model.

Phase behavior: introduction to phase behavior, mechanisms of phase separation-Spinodal decomposition and Nucleation & Growth, and various phase diagrams of

polymer blends. **Morphology**- definition, influence of phase separation on the crystallization and morphology, types of morphologies.

UNIT III COMPATIBILIZATION AND TOUGHENING OF POLYMER 9

Compatibilization (Alloying) Methods: Introduction, types and role of compatibilizer, compatibilization methods, mechanism and properties of compatibilized blends. Degree of compatibilization.

Polymer Toughening: Mechanism and theory of toughening, Toughening of thermoplastics and thermosets; Thermoplastic elastomers (TPEs).

UNIT IV RHEOLOGY OF POLYMER BLENDS 9

Factors affecting morphology of polymer blends, commercial blends, Flow behavior of commercial blends, Rheological properties of polymer blends, rheological criteria, interfacial criteria,synergy & additivity, log-and inverse-additivity rules, effect of interaction parameters on properties, permeability of blends to gases and vapors.

UNIT V INTERPENETRATING POLYMERIC NETWORKS (IPNS): 9

Interpenetrating Polymeric Networks (IPNs): Introduction, classification, method of formation of IPNs, properties and uses, role of cross links, and their importance.

Blends of engineering and commodity plastics: like PVC/ABS, PVC/SAN, PVC/NBR, PC/PET, PC/PBT, PC/ABS and PPO/HIPS [Case study including properties and applications].

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Demonstrate the fundamentals of polymer blends, alloys and blending equipments

CO2: predict the thermodynamic aspects, phase diagram and morphology of polymer blends

CO3: Apply the toughening and compatibilization mechanism in polymer blends

CO4: Illustrate the rheology of polymer blends

CO5: Select appropriate polymer blends that have commercial importance

REFERENCES:

1.Utracki, L.A., 1990. *Polymer blends and alloys.* Hanser Publication.

2.Robeson, M., 2007. *Polymer Blends: A Comprehensive Review.* Hanser Publishers.

3.Paul.and Newman. 1978. *Polymer blends.* Academic press, NewYork, 1978.

4.John Mason. and Leslie, H., 1976. *Polymer blends and composites.* Plenum Press, New York.

5.Singh, R. P., Das, C.K., and Mustafi, S.K.,2002*. Polymer Blends and Alloys-An Overview*. Asian Books Pvt. Ltd.

6. Magurudeniya, D., Huang, P., Gunathilake Elizabeth, S. and Rainbolt, A. 2005. *Polymer Blends-Encyclopedia of Polymer Science and Technology*. John Wiley & Sons.

PE1333 PROCESS INSTRUMENTATION

L	T	P	C
3	0	0	3

OBJECTIVES:

- To make the student learn about temperature measurement and pressure, level and flow measurement.
- To acquaint the student physical property measurement in and process chemical analyzer.
- To know the importance of Indicating and recording instruments

UNIT I TEMPERATURE MEASUREMENT 9

Introduction-Classification of temperature measuring device – thermocouple-Resistance thermometers- thermistor-radiation pyrometry-Total radiation pyrometers - optical pyrometers.

UNIT II PRESSURE, LEVEL AND FLOW MEASUREMENT 9

Pressure –manometers, bourdan tube –bellow diaphragam, Venturi, Orifice & nozzle meters, Pitot tube, turbine type meters, hot wire anemometer, magnetic flow meters. Level measurement: float level meters & electrical conductivity meters.

UNIT III PHYSICAL PROPERTY MEASUREMENT 9

Measurement of Density and specific gravity – Measurement of viscosity thermal conductivity measurement-Measurement of viscosity.

UNIT IV PROCESS CHEMICAL ANALYZER 9

Chromatographic analyzers, infrared analyzers, ultraviolet and visible radiation analyzers mass spectrometers, electro analytical instruments.

UNIT V INDICATING AND RECORDING INSTRUMENTS 9

Recorders-recorder requirements, analog and digital recording instruments, ultraviolet recorder, Null type recorder, single point recorder.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Select the suitable temperature measuring device for the application.
CO2: Measure the flow measurement using instruments.
CO3:Relate the Physical property measurement and the industrial operations
CO4: Use the various chemical analyzers for the suitable application.
CO5: Select the various recorders for the industrial applications.

REFERENCES

1. Sawhney, A.K. and Sawhney, P., 1995. *A course in mechanical measurements and instrumentation* (Vol. 3, p. 12). Dhanpat Rai, New Delhi.
2..Khandpur, R.S ., 2004, *Analytical Instrumentation* , Tata McGraw-Hill, 5th edition New Delhi.

3. Fribance, A.E., 1983. *Industrial Instrumentation Fundamentals*, McGraw Hill Co. New York.
4. Eckman, D.P., 2004. *Industrial Instrumentation*, CBS publishers.
5. Rebert, Perry H. 2007. *Chemical Engineering Hand Book*, 8thEdn.,McGraw Hill .,Inc. New York.
6. Dunn, W.C., 2005. *Fundamentals of industrial instrumentation and process control* (Vol. 681). McGraw-Hill.

PE1334 SMART MATERIALS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To enable the students to understand the concepts on smart materials,
- To impart basic knowledge on electro active compounds, and sensor,
- To gain knowledge in light emitting display and novel drug delivery

UNIT I INTRODUCTION TO SMART MATERIALS 9

Introduction- Advantages of smart polymers- Classification of smart polymers - Classes of materials – Smart/intelligent materials – Overview of Smart Materials- Principles of Piezoelectricty, Piezoelectric Materials, Principles of Magnetostriction, Introduction to Electro-active Materials, Ionic Polymer Matrix Composite (IPMC), Shape Memory materials

UNIT II ELECTROACTIVE ORGANIC COMPOUNDS 9

Basic Principle and Compounds - Organic Piezoelectric, Pyroelectric and Ferroelectric -Acids and Bases; Ions; Solvents; Functional Groups; Aromatic Compounds; Conductive Polymers; Buckyballs and Nanotubes; Fullerenes; Carbon Nanotubes, Optical and electrical properties of nano tubes and nano wires – quantum wires and quantum dots.

UNIT III POLYMER FILM IN SENSOR APPLICATION 9

Sensor technology: Thin Film and Thick Film Technology-Processing of Micro Sensor Polymer Film Sensor structure with Sensitive Polymer: Impedance type sensor,-Calorimetric Sensor- Fiber Optic Sensor.

UNIT IV ORGANIC LIGHT-EMITTING DISPLAYS 9

Device Efficiency; Methods of Efficiency Improvement; Full-Colour Displays; Electronic Paper

Photovoltaic Cells - Organic Semiconductor Solar Cell, Dye-Sensitized Solar Cell; Luminescent Concentrator.

UNIT V INNOVATIONS IN NOVEL DRUG DELIVERY 9

Mechanism of action and its examples: pH sensitive smart polymers- Temperature sensitive smart polymers- Polymers with dual stimuli-responsiveness- Phase sensitive smart polymers -Light sensitive smart polymers.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Express the principle behavior of smart materials.

CO2: Construct the conductive behavior of electro-active organic compounds and Nanomaterial

CO3: Illustrate the physical principles and and fabrication methods of sensor

CO4: Determine the efficiency of light emitting plastic in electronics

CO5: Demonstrate the mechanism of drug delivery of smart polymer

REFERENCES:

1.Gandhi, M.V. and Thompson, B.D., 1992. *Smart materials and structures*. Springer Science & Business Media.

2.Duerig, T.W., Melton, K.N. and Stöckel, D.W.C.M., 2013. *Engineering aspects of shape memory alloys*. Butterworth-Heinemann.

3.Poole Jr, C.P. and Owens, F.J., 2003. *Introduction to nanotechnology*. John Wiley & Sons.

4.Chatterji, T. ed., 2012. *Colossal magnetoresistive manganites*. Springer Science & Business Media.

5.Lines, M.E. and Glass, A.M., 2001. *Principles and applications of ferroelectrics and related materials*. Oxford university press.

6.Mahajan, A. and Aggarwal, G., 2011. Smart polymers: innovations in novel drug delivery. *Int. J. Drug Dev. Res*, *3*(3), pp.16-30.

OPE151	HIGH PERFORMANCE POLYMERS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To learn about the general methods of preparation of heat resistant polymer materials
- To study the general properties, processing behavior of conducting and photosensitive materials.
- To provide the knowledge in applications of different class of specialty plastics materials.

UNIT I HEAT RESISTANT POLYMERS 9

Requirements for heat resistance, Determination of heat resistance, Synthesis, Structure-property relationships, Applications of heat resistant polymers like polyamides, polyimides and its derivatives, polyquinolines, polyquinoxalines, PBT, PBO, PBI, PPS, PPO, PEEK, engineering plastic

UNIT II LIQUID CRYSTALLINE POLYMERS 9

Concept of liquid crystalline phase, Theories of liquid crystallinity, Characteristics of LC state and LCPs, Rheology of liquid crystalline polymers, Blends of LCPs, Self reinforced composites, Applications.

UNIT III CONDUCTING POLYMERS 9

Conduction mechanism, semi-conductors and conducting polymers, Band theory, Doping of polymeric systems, Processing and testing of conducting polymers, Applications and recent advances in conducting polymers.

UNIT IV PHOTOSENSITIVE POLYMERS 9

Introduction, Classification, Synthesis of photosensitive polymers, Curing reactions, Photoresists, Photolithography, Applications.

UNIT V POLYMERS IN SPECIALTY APPLICATIONS 9

Polymers in agricultural applications, Green houses, Mulches, Control release of agricultural chemicals, Seed coatings, Polymers in construction and building applications.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Acquire knowledge on manufacturing, properties and applications of heat resistant polymers

CO2: Correlate the liquid crystalline polymers, blends and composites manufacturing methods, properties and applications

CO3: Correlate the conducting polymers manufacturing methods, properties, and applications.

CO4: Photosensitive polymers analysis and understand the consequence of different types

CO5: Explain the methods of preparation , properties and applications of speciality polymers

REFERENCES:

1. Mittal, V. ed., 2011. *High performance polymers and engineering plastics*. John Wiley & Sons

2. Kemmish, D.J., 2011. Practical *guide to high performance engineering plastics*. Smithers Rapra.

3.Brydson, J.A., 2016. *Brydson's Plastics Materials*. Butterworth-Heinemann.

4.Athalye, A.S., 1991. *Plastics: Materials Handbook*. Multi-Tech Publishing Company

OPE152	INDUSTRIAL SAFETY	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To learn about implementation of the safety procedures,
- To acquire the knowledge in risk analysis and assessment,
- To understand the basic of Hazard identification, chemical hazards , and plant hazards

UNIT I NEED FOR SAFETY IN INDUSTRIES 9

Scientific principles, Engineering aspects of industrial safety in relation to economic and operational aspects, Safety regulations, Safety Programmes – components and realization; Potential hazards – extreme operating conditions, toxic chemicals; safe handling, Plant and equipment start up and shut downs, Safe Commissioning of Plant

UNIT II RISK ANALYSIS AND ASSESSMENT 9

Overall risk analysis--emergency planning-on site & off site emergency planning, risk management ISO 14000, EMS models case studies. Quantitative risk assessment - rapid and comprehensive risk analysis; Risk due to Radiation, explosion due to over pressure, jet fire-fire ball.

UNIT III TOOLS FOR HAZARDS IDENTIFICATION 9

HAZOP, HAZAN Consequence analysis Fault Tree, Event Tree, LEL, UEL, Safety Audits.etc. Event probability and failure frequency analysis. Hazop study-case studies-pumping system-reactor-mass transfer system.

UNIT IV CHEMICAL HAZARDS 9

Classification of chemical hazards, Chemical as cause of occupational diseases – dust,fumes, gases and vapors; Industrial hygiene, Hazard analysis and health management;

UNIT V PLANT HAZARDS 9

Engineering control of chemical plant hazards, Intensification and attenuation of hazardous materials, Industrial plant layout, Ventilation and lighting, Electrical system, Instrumentation etc, Fire prevention

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Demonstrate the awareness of plant safety in selection and layout of chemical plants.

CO2: Analysis the quantitative risk in various parameters in chemical plants.

CO3: Express the skill in classifying fire, explosion hazards in mass transfer systems.

CO4: Solve the chemical hazards related to occupational diseases.

CO5: Describe plant safety measures and plant layout

REFERENCES:

1.Crowl, D.A. and Louvar, J.F., 2001. *Chemical process safety: fundamentals with applications*. Pearson Education.

2.Fawcett, H.H. and Wood, W.S., 1982. *Safety and accident prevention in chemical operations*. Wiley.

3.Hyatt, N., 2018. *Guidelines for process hazards analysis (PHA, HAZOP), hazards identification, and risk analysis*. CRC press.

4.Heinrich, H.W., Petersen, D. and Roos, N., 1980. *Industrial Accident Prevention*. McGraw Hill-New York.

5.Taylor, J.R., 1994. *Risk analysis for process plant, pipelines and transport*. Taylor & Francis

		L	T	P	C
OPE153	**POLYMER ENGINEERING**	**3**	**0**	**0**	**3**

OBJECTIVES:

- To acquire the knowledge of basic of polymers terminology.
- To impart basic knowledge on polymer processing and mold design.
- To gain knowledge of polymers in water treatment and biomedical applications

UNIT I BASICS OF POLYMERS 9

Introduction: Introduction to Historical Background of Polymer Science, Various applications of polymers, Raw materials, Market and future of polymers, Macromolecular concept, structural features of polymers, Terminology: Basic concepts and terminology like monomers, oligomers, telomers, polymers, low polymers, high polymers, copolymers, functionality, degree of polymerization, thermoplastics, thermosets, elastomers/rubbers, plastics, fibers, adhesives.

UNIT II CLASSIFICATION OF POLYMERS 9

Classification based on structure, origin, fabrication, properties etc. Linear, branched, crosslinked polymers etc. Classification Nomenclature of polymers, Crystalline and Amorphous polymers.

Polymerization techniques-bulk-solution-suspension and emulsion. Brief idea of polyethylene, polypropylene, polystyrene, polyvinyl chloride, Novolac and resol, natural rubber, Styrene butadiene rubber, Adhesives, Fibers and surface coatings, Blends.

UNIT III POLYMER PROCESSING 9

Introduction to polymer processing - Plastics process techniques - Injection moulding – Principle- Types of Injection unit – Types of Clamping unit- Clamping tonnage calculation. Basic Principle and Types of Extruders, Compression moulding ,Transfer moulding

UNIT IV DESIGN OF MOLD 9

Design features of standard mold components, materials used for Mold, Feed system: types of runners, runner layout, runner design; runner balancing, types of gates. Different methods of ejection, Cooling system

UNIT V POLYMERS APPLICATIONS **9**

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

Polymers in electrical and electronics industry, Polymers for high temperature resistance, polymer membrane – polymer complexes for water treatment.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Distinguish the oligomers and polymers.

CO2: Classify the polymer and suggest the suitable polymerization techniques to convert monomer to polymer

CO3: Select the suitable polymerization process for converting polymer materials into products

CO4: Develop the mold components for polymer products

CO5: Apply the polymers in water treatment and biomedical areas

REFERENCES:

1. Billmeyer, F.W., 1984. *Textbook of polymer science*. John Wiley & Sons
2. Odian, G., 2004. *Principles of polymerization*. John Wiley & Sons.
3. Mark, H.F. and Kroschwitz, J.I., 1985. *Encyclopedia of polymer science and engineering*.
3. Donald, A.M., Windle, A.H. and Hanna, S., 2006. *Liquid crystalline polymers*. Cambridge University Press.
4.Chanda, M. and Roy, S.K., 2008. *Industrial polymers, specialty polymers, and their applications* (Vol. 74). CRC press.
5. Dyson, R.W., 1991. *Engineering polymers*. Springer Science & Business Media.

OPE154 POLYMERS IN ELECTRICAL & ELECTRONICS APPLICATIONS

L	T	P	C
3	0	0	3

OBJECTIVES:

- To make the student acquire knowledge on conducting polymers.
- To provide exposure on synthesis of conducting polymers.
- To impart a thorough understanding of doping process of conducting polymers.
- To provide knowledge on properties of conducting polymers.
- To facilitate the students to understand the use of conducting polymers for various applications.

UNIT I BASICS OF CONDUCTING POLYMERS 9

Introduction - Electrically conducting polymers- Chain growth polymerisation, step growth polymerization, electrochemical polymerization, Metathesis polymerization(Ring opening metathesis polymer (ROMP). Advantages and disadvantages of conducting polymers, methods to enhance the processability of conducting polymers. Effect of polymer structure on electrical properties- Chemical and physical variant, conformation and hindered rotation, co polymers, crystallization and orientation.

UNIT II SYNTHESIS OF CONDUCTING POLYMERS 9

Theories of conduction -Band theory of conduction, properties of semi conductors, hopping conduction .Synthesis and properties of conducting polymers- Polyacetylene, Poly p-phenylene, Polyheterocyclic and polyaromatic conducting polymers like polythiophene, poly vinyl carbazole, polypyrene, polyaniline, Polypyrrole, Poly phenylene vinylene, Polypyridine

UNIT III CONDUCTING POLYMER DOPING PROCESS 9

Valance Band theory- basic concepts of band model, band model of conductor, semiconductor and insulator. Carrier mobility, intrachain conductivity, interchain conductivity. Concept of doping- Charge carriers: polarons, bipolarons and solitons. Types of dopants, oxidative dopants and reductive dopants, mechanism of doping, p-type doping and n-type doping, inorganic and organic dopants, effect of doping on the dielectric properties of conducting polymers.

UNIT IV PROPERTIES OF CONDUCTING POLYMERS 9

Dielectric properties of conducting polymers in the high and very high frequency fields (a.c field), ultra high frequency field (Microwave field) . Dielectric constant, dielectric loss and absorption property of conducting polymers in the a.c and microwave fields. Applications of Electro-active polymers – xerography, OLEDS and Solar cells. Non-linear optics, intrinsically conductive polymers – soft electronics, LEDs, Photovoltaic devices, Sensors.

UNIT V APPLICATIONS OF CONDUCTING POLYMERS 9

Basic structural characteristics and properties of conjugated polymers- electrical conductivity, photoconductivity, charge storage capacity, photoluminescence, and electroluminescence. Applications of conducting polymers- Polymer rechargeable batteries, sensors, electrochemical actuators, electro luminescent applications. Conductivity applications: antistatic coatings- conducting adhesives-artificial nerves. Electronic applications: EMI shielding, Frequency selective surfaces, satellite communication links.

TOTAL: 45 PERIODS

OUTCOMES:

Upon successful completion of this course, students will be able to

CO1: Attain the basic knowledge on conducting polymers.

CO2: Demonstrate synthesis of conducting polymers
CO3:Develop the capacity of doping of conducting polymers
CO4: Analyze the properties of conducting polymers
CO5: Identify the use of conducting polymers for various applications.

REFERENCES:

1.Chandrasekhar, P., 1999. *Conducting polymers, fundamentals and applications*. Kluwer academic publishers

2. Skotheim, T.A. ed., 1997. *Handbook of conducting polymers*. CRC press

Nalwa, H.S., 1997. *Handbook of organic conductive molecules and polymers*. Wiley.

3.Mark Bikales over Berger Menges 2nd edition, Vol.5 .1986. *Encyclopaedia of Polymer science and Engineering,*John Wiley and Sons Inc.

4.Lyons, M.E.O., 1994 *Electroactive polymers*, Plenum Press.

5.Blythe, A.R., 1979. *Electrical properties of polymers,* Cambridge University Press.

6.Margolis, J., 1993. *Conducting Polymers and Plastics*, Chapman and Hal.

Blythe.T and Bloor.D,2005.*Electrical properties of polymers*, Cambridge Uni.Press

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