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

B.Tech. POLYMER TECHNOLOGY

REGULATIONS - 2020 - AUTONOMOUS

CHOICE BASED CREDIT SYSTEM

I TO VIII SEMESTERS CURRICULUM AND (III - VIII SEM) 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 Technology with a commitment to quality, timeliness and compete with confidence in their career

PEO 2:. Graduates will contribute towards research and Professional development and entrepreneurship

PEO 3: Graduates will engage in lifelong learning or continuous education Opportunities.

Program Specific Outcomes (PSOs):

PSO1. Polymer industry oriented preparedness: Reveal an ability to identify careers in polymer technology's domains like, synthesis of polymers, processing and quality with adept skills required to work in polymer technology laboratory or manufacturing facility.

PSO2. Higher Education Preparedness: Demonstrate an ability to appear for competitive examinations to pursue higher studies.

The credit requirement for the programme B.Tech. Polymer Technology (as per Regulation 2020) is outlined below:

SEMESTER VII

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1	PT1701	Polymer Composites	PC	3	3	0	0	3
2	PT1702	Rubber Product Manufacturing	PC	3	3	0	0	3
3	GE1671	Total Quality Management	HS	3	3	0	0	3
4		Professional Elective III	PE	3	3	0	0	3
5		Professional Elective IV	PE	3	3	0	0	3
6		Open Elective II	OE	3	3	0	0	3
PRACTICALS								
7	PT1711	Computer Aided Mold Design Laboratory -II	PC	4	0	0	4	2
8	PT1712	Polymer blends and composites Laboratory	PC	4	0	0	4	2
9	PT1721	Mini project	EEC	2	0	0	4	2
			TOTAL	28	18	0	12	24

SEMESTER VIII

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1		Online course-II	OL	3	3	0	0	3
2	PT1821	Project Work	EEC	8	0	0	16	8
			TOTAL	11	3	0	16	11

SEMESTER VII, ELECTIVE III

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1	PT1731	Biodegradable Polymers	PE	3	3	0	0	3
2	PT1732	Fiber Technology	PE	3	3	0	0	3
3	PT1733	Plastics Packaging Technology	PE	3	3	0	0	3
4	PT1734	Polymer Structure Property Relations	PE	3	3	0	0	3
5	PT1735	Polymers In Civil and geopolymer	PE	3	3	0	0	3

SEMESTER VII, ELECTIVE IV

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
1	PT1736	Paints and Surface Coatings	PE	3	3	0	0	3
2	PT1737	Polymers for Aerospace applications	PE	3	3	0	0	3
3	PT1738	Process Instrumentation for Polymer Technologist	PE	3	3	0	0	3
4	PT1739	Specialty Elastomers	PE	3	3	0	0	3
5	PT1740	Tyres and Tubes Technology	PE	3	3	0	0	3

SEMESTER VIII - ONLINE

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
THEORY								
1		Online course-II	OL	3	3	0	0	3

SEMESTER-VII, OPEN ELECTIVE – II (Offered by PT department)

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	CONTACT PERIODS	L	T	P	C
Offered to all discipline								
1	OPT161	Introduction to macromolecular science	OE	3	3	0	0	3
2	OPT164	Polymer Processing Technology	OE	3	3	0	0	3
Offered to Mech, MTR, EI, EEE								
3	OPT162	Introduction to Product Testing	OE	3	3	0	0	3
4	OPT163	Polymer Nanocomposites	OE	3	3	0	0	3

SEMESTER VII

PT1701	POLYMER COMPOSITES	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To enable the students to understand the introduction and classification of composites
- To understand the various reinforcements for composites
- To impart the various matrix systems in composites
- To acquire knowledge about various processing methods of composites
  To understand the testing and applications of composites

UNIT I INTRODUCTION TO COMPOSITES 9

Composites - classifications - metal matrix composites, ceramic matrix composites, Polymer matrix composites - Advantages and limitations of polymer matrix composites over MMC and CMC, hybrid composites general properties and applications

UNIT II REINFORCEMENTS FOR COMPOSITES 9

Reinforcements: Properties and applications of - various types of glass fiber, carbon fibers, aramid fibers, boron fibers, natural fibers.

UNIT III MATRIX FOR COMPSOITES 9

Methods of manufacturing- properties, curing characteristics and applications of unsaturated polyesters - vinyl ester -phenol formaldehyde resin-urea formaldehyde resin-melamine formaldehyde resin. epoxy resins, Cyanate esters resins. Polyimide resin

UNIT IV PROCESSING OF COMPOSITES 9

Composites Processing techniques - Hand Lay-Up, Spray- Up, Bag Molding, Resin Transfer Molding (RTM), Filament Winding, Pultrusion, Prepregs, SMC, DMC. Autoclave molding, centrifugal molding

UNIT V TESTING AND APPLICATIONS OF COMPOSITES 9

Mechanics of composites - Fracture and damage mechanics - laminates – delamination - Measurement of physical and mechanical properties: density-fibre volume fraction-void content, test for tensile-compression - flexural in fiber direction

APPLICATIONS OF COMPOSITES

Applications in aerospace, automotive, marine, civil engineering and electrical industry

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 **:** Familiarize about the introduction and classification of composites

CO2 **:** Attain the knowledge of reinforcement mechanism

CO3 **:** Explain the matrix for composites

CO4 **:** understand the processing methods of composites

CO5 **:** knowledge in testing and applications of composites

TEXT BOOKS:

1. Lubin. G., 1982. *Hand Book of Composites*. Van Nostrand Reinhold, New York.
2. Peters. S.T., 1998. *Handbook of Composites*. Chapmun & hall. 2nd Edition

REFERENCES:

1. Hull. D., and Clyne. T.W., 1996. *An introduction to Composite Materials* 2nd Ed.,Cambridge.
2. Matthews. F. L., and Rawlings. R.D., 1994. *Composite materials: engineering and science*. Chapman and Hall.
3. Mallick. P.K., 1997. *Composites Engineering Handbook*. Marcel Dekker Inc.
4. Brydson. A., 1995. *Plastics materials*. Butterworth- Heinemann – Oxford
5. Hull. D., and Clyne. T.W., 1996. *An introduction to Composite Materials* 2nd Ed., Cambridge.

PT1702	RUBBER PRODUCT MANUFACTURING	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To make the students to acquire knowledge in basic machining operations
- To impart knowledge in EDM and Electroforming process
- To make the students to acquire knowledge in measuring instruments

UNIT I TYRE MANUFACTURING 9

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

UNIT II BELT AND HOSES MANUFACTURING 9

Belting and Hoses - Conveyor belting, passenger conveyor belting, - Components and Functions - V Belts - Building & Manufacturing - Hose-Types- moulded, machine, handmade- Compounding aspects

UNIT III FOOTWEAR AND SPORTS GOODS MANUFACTURING 9

Footwear and Sports Goods - Footwear Components- sole and heel units - Various manufacturing process - Sports Goods - Tennis Balls - Golf Balls- Tennikoit rings

UNIT IV OIL SEALS AND ENGINE MOUNT MANUFACTURING 9

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

UNIT V LATEX PRODUCTS MANUFACTURING 9

Latex Products - Dipped goods - rubber band, Gloves, balloon - Manufacturing of Latex Foam Rubber thread, use of latex in cement, adhesives, road rubberisation - Rubber Recycling products.

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 process

CO2 : suggest suitable rubber composition for making rubber hoses and belts

CO3 : demonstrate footwear and sport goods manufacturing techniques

CO4 : apply rubber-metal bonding principles for making oil seals and other molded goods

CO5 : suggest suitable process for making of latex dipped goods and rubber recycled products

TEXT BOOKS:

1. Bhowmick, A. ed., 2018. *Rubber products manufacturing technology*. Routledge.
2. Ciesielski, A., 1999. *An introduction to rubber technology*. iSmithersRapra Publishing.
3. Morrell, S.H. and Blow, C.M., 1975. Rubber technology and manufacture. *Blow, CM, Ed*.
4. Mark, J.E., Erman, B. and Roland, M. eds., 2013. *The science and technology of rubber*. Academic press.

REFERENCES:

1. Franta, I. ed., 2012. *Elastomers and rubber compounding materials* (Vol. 1). Elsevier.
2. Morton, M. ed., 2013. *Rubber technology*. Springer Science & Business Media.
3. Gent, A.N., 2012. *Engineering with rubber: how to design rubber components*. Carl HanserVerlag GmbH Co KG.

GE1671 **TOTAL QUALITY MANAGEMENT** **L T P C**
(Common to all Branches) **3 0 0 3**

OBJECTIVES:

- Learn the concepts of quality and quality management, TQM framework, Barriers and Benefits of TQM.
- Apply the Principles and techniques of Quality Management for real time
- Understanding the need and importance of quality assurance and certification

UNIT I INTRODUCTION 9

Concept of Quality and Quality Management - Determinants of quality of product & service- Quality vs. Reliability - Definition of TQM - Basic concepts of TQM - TQM Framework - Barriers to TQM - Benefits of TQM.– Gurus of TQM (Brief introduction) - Quality statements - vision, mission, Policy.

UNIT II PRINCIPLES AND PHILOSOPHIES OF QUALITY MANAGEMENT 9

Overview of the contributions of Deming , Juran Crosby, Masaaki Imai, Feigenbaum, Ishikawa, Taguchi, Shingeo and Walter Shewhart - Concepts of Quality circle, Japanese 5S principles and 8D methodology.

UNIT III TOOLS AND TECHNIQUES FOR QUALITY MANAGEMENT 9

Quality functions development (QFD) - Benefits, Voice of customer, information Organisation, House of quality (HOQ), building a HOQ, QFD process. Failure mode effect analysis (FMEA) - requirements of reliability, failure rate, FMEA stages, design, process and documentation -Taguchi techniques

UNIT IV STATISTICAL QUALITY CONTROL 9

Juran's concept of quality cost-components of Quality Cost- Statistical Quality Control - Inspection, Sampling, Sample Size, Sampling Plan, AQL, OC curve, Producer Risk, Consumer Risk, AOQ, AOQL, Control Charts & Control Limits - X, R & S charts and their application - causes of variations – Assignable & Random; Runs -Test, Chart-Sensitivity Test and Run-Sum Test; Normal-Distribution curve and concept of Six Sigma

UNIT V QMS - QUALITY MANAGEMENT SYSTEM 9

Introduction - Benefits of ISO Registration-ISO 9000 Series of Standards-Sector-Specific Standards - AS 9100, TS16949 and TL 9000 - ISO 9001 Requirements - Implementation-Documentation-Internal Audits-Registration-ENVIRONMENTAL MANAGEMENT SYSTEM: Introduction-ISO 14000 Series Standards-Concepts of ISO 14001-Requirements of ISO 14001-Benefits of EMS

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon successful completion of course the students will be able to

CO1: Ability to apply TQM concepts in a selected enterprise.

CO2: Ability to apply TQM principles in a selected enterprise.

CO3: Ability to understand Taguchi's techniques, Performance Measures,QFD,HOQ .

CO4: Ability to understand Six Sigma and apply Traditional tools, New tools, Benchmarking.

CO5: confirm quality standards and implementing QMS in business organization

TEXT BOOKS:

1. L. Suganthi & Dr. Anand Samuel (2004), Total Quality Management – Prentice Hall, Publications.
2. Dale H.Besterfiled, Carol B.Michna,Glen H. Besterfield, MaryB.Sacre, Hemant Urdhwareshe and Rashmi Urdhwareshe, “Total Quality Management”, Pearson Education Asia, Revised Third Edition, Indian Reprint, Sixth Impression,2013.

REFERENCES:

1. Rose J.E. - “Total Quality Management” 1997, S. Chand & Co.,
2. Kiran.D.R, “Total Quality Management: Key concepts and case studies, Butterworth - Heinemann Ltd, 2016
3. Shridhara Bhat K, “Total Quality Management: Text and Cases”, Himalaya Publishing House India, 2016(2nd Edition), ISBN: 9789352622399

PT1711	COMPUTER AIDED MOLD DESIGN LAB-II	L	T	P	C
		3	0	0	3

OBJECTIVES:

To enable the students to,

- Design of Extrusion die for thermoplastic products
- Design of blow mold for plastic bottles
- Design of compression and transfer mold for thermoset products

LIST OF EXERCISES

1. Design of convergent and divergent dies for extrusion
2. Design of Extrusion die for plastic pipes
3. Design of Extrusion die for blown films
4. Design of Extrusion die for plastic sheets
5. Design of open flash type compression mold for given product
6. Design of positive type compression mold for given product
7. Design of semi-positive type compression mold for given product
8. Design of plunger type transfer mold for given product
9. Design of pot type transfer mold for given product
10. Design of blow mold for plastic bottle
11. Design of blow mold for plastic containers
12. Design of rotational mold for given product

(Any 10 experiments from above)

TOTAL: 60 PERIODS

OUTCOMES:

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

CO1 **:** Design extrusion die for platic sheets, films and pipes using CAD software

CO2 **:** Design compression mold for thermoset products

CO3 **:** Design transfer mold for thermoset products

CO4 **:** Design blow mold for bottles and containers

CO5 **:** Design of rotational mold for plastic product

LIST OF EQUIPMENT FOR A BATCH OF 60 STUDENTS:

S. No.	Description of Equipment	Quantity Required
1.	CAD Software License	1 No
2.	Printer	1 No

REFERENCES:

1. Donaldson, C., LeCain, G.H., Goold, V.C. and Ghose, J., 2012. *Tool design*. Tata McGraw-Hill Education.
2. Crawford, R.J. and Martin, P.J., 2020. *Plastics engineering*. Butterworth-Heinemann.

1. Agassant, J.F., Avenas, P., Carreau, P.J., Vergnes, B. and Vincent, M., 2017. *Polymer processing: principles and modeling*. Carl HanserVerlag GmbH Co KG.
2. Baird, D.G. and Collias, D.I., 2014. *Polymer processing: principles and design*. John Wiley & Sons.
3. Lafleur, P.G. and Vergnes, B. eds., 2014. *Polymer extrusion*. John Wiley & Sons

PT1712	POLYMER BLENDS AND COMPOSITES LAB	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To generate skills on production of polymer blends
- To impart the knowledge to make the composites using compression molding
- To develop the composite using hand lay up process

LIST OF EXERCISES

1. Miscible binary system (solution and melt mixing)
2. Immiscible binary system (solution and melt mixing)
3. Compatibilised binary system (solution and melt mixing)
4. Blending of NR with SBR, BR and EPDM.
5. Preparation of Continuous Fiber reinforced Polymer Composites using Hand Lay up technique.
6. Preparation of Continuous Fiber reinforced Polymer Composites using Compression molding technique.
7. Preparation of Dis-Continuous Fiber reinforced Polymer Composites using Hand Lay up technique
8. Preparation of Dis-Continuous Fiber reinforced Polymer Composites using Compression molding technique
9. Preparation of thermoplastic fiber composites using compression moulding
10. Preparation of compression moulded random fiber composites based on thermosets
11. Preparation of compression moulded bidirectional fiber composites based on thermosets
12. Preparation of compression moulded unidirectional fiber composites based on thermosets
13. Preparation of compression moulded random fiber composites based on elastomers
14. Preparation of compression moulded unidirectional fiber composites based on Elastomers
15. Casting

(Any eight experiments)

TOTAL: 60 PERIODS

OUTCOMES:

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

CO1 : Prepare the miscible binary system

CO2 : Illustrate the immiscible and compatibilised binary systems

CO3 : Develop Continuous and discontinuous fiber composites

CO4 : Manufacture the unidirectional, unidirectional and random fiber composites

CO5 : Make the composite using casting process

LIST OF EQUIPMENT FOR A BATCH OF 60 STUDENTS:

REFERENCES:

1. Robeson. M.L., 2007. *Polymer Blends*. Hanser Gardner publications, U.S.A.
2. Bucknall. C.B. and Paul. D.R., 2000. *Polymer Blends*. John Wiley and Sons. New York.
3. Shonaike. O. and Simon. P., 1999. *Polymer Blends and Alloys.* Marcel Dekker.
4 Mallick. P.K., 2017. *Processing of Polymer Matrix Composites: Processing and Applications.* Taylor and Francis group.
5 Holloway. L., 1994. *Hand Book of Composites for Engineer*s, Technomic Lancaster.

LIST OF EQUIPMENT FOR A BATCH OF 60 STUDENTS:

S. No.	Description of Equipment	Quantity Required
1	Compression molding	1
2	Mold for hand layup	1
3	Fibers	Required

SEMESTER VIII

		L	T	P	C
PT1821	**PROJECT WORK**	**0**	**0**	**20**	**10**

Each student will be assigned a project involving some design and fabrication work as well as theoretical and experimental studies on issues related to Polymer Technology. Continuous internal assessment marks for the project will be given during project review meeting. The student has to prepare and present a detailed project report at the end of the semester and give a presentation about the work done. End semester examination mark will be based on viva voce examination.

ELECTIVE III

PT1731	BIODEGRADABLE POLYMERS	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To enable the students to understand the method to develop biodegradable polymers
- To get knowledge on need of biodegradable polymer.
- To enrich various testing methods used for analyzing the biodegradability.

UNIT I CHEMISTRY AND BIOCHEMISTRY OF POLYMER DEGRADATION 9

Introduction, enzymes - enzyme nomenclature - enzyme specificity - physical factors affecting the activity of enzymes - enzyme mechanism, Chemical degradation initiates biodegradation, Hydrolysis of synthetic biodegradable polymers.

UNIT II PARTICULATE STARCH BASED PRODUCTS 9

Development of Technology, Current objectives, relative starch technology, Manufacture of master batch, Conversion technology - processing precautions - moisture and temperature - rheological considerations, cyclic conversion process, physical properties of products - sample preparation - physical testing methods

UNIT III BIOPOLYESTERS 9

Introduction, History, biosynthesis, Isolation - solvent extraction - sodium hypo chloride digestion, enzymatic digestion, Properties - crystal structure - nascent morphology, degradation-Intracellular biodegradation - extra cellular biodegradation - thermal degradation - hydrolytic degradation - environmental degradation

UNIT IV RECYCLING TECHNOLOGY FOR BIODEGRADABLE PLASTICS 9

Introduction, conventional recycling - recycling problems, degradable complicate recycling- polyethylene/starch film, reprocessing polyethylene/cornstarch film scrap - learning to reprocess PE/S - Calcium oxide moisture scavenger -temperature control - accounting for pro-oxidant - handling PE/S repro - economics of in-plant recycling, Using PE/S repro - comparative study of PE/S repro on film properties, recycling other degradables.

UNIT V TEST METHODS & STANDARDS FOR BIODEGRADABLE PLASTICS 9

Introduction, defining biodegradability, criteria used in the evaluation of biodegradable polymers, choosing the most appropriate methodology, description of current test methods - screening test for ready biodegradability, tests for inherent biodegradability, tests for simulation studies, - petri dish screen -environmental chamber method - soil burial tests

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 : Develop the synthetic biodegradable polymers.

CO2 : Express the particulate starch, conversion technology of starch processing.

CO3 : Examine the biosynthesis, degradation-Intracellular biodegradation

CO4 : Illustrate the recycle of biodegradable polymer.

CO5 : Expose the test method and standards for biodegradable polymer.

TEXT BOOKS:

1. Griffin, G.J., 1994. *Chemistry and technology of biodegradable polymers*. Blackie Academic and Professional.
2. Doi, Y. and Fukuda, K. eds., 2013. *Biodegradable Plastics and Polymers: Proceedings of the Third International Scientific Workshop on Biodegradable Plastics and Polymers, Osaka, Japan, November 9-11, 1993*. Elsevier.
3. Domb, A.J., Kost, J. and Wiseman, D. eds., 1998. *Handbook of biodegradable polymers* (Vol. 7). CRC press.

REFERENCES:

1. Bastioli, C. ed., 2020. *Handbook of biodegradable polymers*. Walter de Gruyter GmbH & Co KG.
2. Lendlein, A. and Sisson, A. eds., 2011. *Handbook of biodegradable polymers: isolation, synthesis, characterization and applications*. John Wiley & Sons.
3. Ebnesajjad, S. ed., 2012. *Handbook of biopolymers and biodegradable plastics: properties, processing and applications*. William Andrew.
4. Perrin, D.E. and English, J.P., 1997. *Handbook of biodegradable polymers.* Domb, AJ, p.63.
5. Thakur, V.K., Thakur, M.K. and Kessler, M.R., 2017. *Handbook of composites from renewable materials, biodegradable materials* (Vol. 5). John Wiley & Sons.

PT1732	FIBER TECHNOLOGY	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To learn about the selection of fiber forming polymers
- To learn about the production technologies of synthetic fibres such as melt spinning, wet spinning, dry spinning, texturing and stretching methods; colouration techniques of fibres.
- To learn about fibre drawing process, modification and testing fibre

UNIT I CRITERIA FOR FIBRE FORMING POLYMERS 11

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 FIBRE PRODUCTION METHODS 12

Production of 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 FIBRE DRAWING PROCESSES 12

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 FIBRES 5

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

UNIT V TESTING OF YARN AND FIBRES 5

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 **:** Analyze the different commercial production of polymers fiber

CO2 : Express the production techniques for fiber formation.

CO3 : Demonstrate the production of fiber drawing process

CO4 : Explore the modified synthetic fibre processing

CO5 : Diagnose the testing of yarn and fiber

TEXT BOOKS:

1. Vaidya, A.A., 1988. *Production of Synthetic Fibres*. Prentice-Hall of India Private Limited.
2. Fourné, F., 1999. *Synthetic fibers: machines and equipment, manufacture, properties*. Hanser.
3. Gupta, V.B. and Kothari, V.K. eds., 2012. *Manufactured fibre technology*. Springer Science & Business Media.

REFERENCES:

1. Mishra, S.P., 2000. *A text book of fibre science and technology*. New Age International.
2. Brody, H., 1994. *Synthetic fibre materials*. Longman.
3. Gabara, V. and Brody, H., 1994. *Synthetic Fibre Materials.*
4. Burkinshaw, S.M., 1995. *Chemical principles of synthetic fibre dyeing*. Springer Science & Business Media.

PT1733	PLASTICS PACKAGING TECHNOLOGY	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To introduce the need and importance of plastic packaging.
- To provide knowledge of various packaging materials
- To impart knowledge on flexible rapid packaging
- To impart knowledge of rigid packaging
- To develop knowledge of various standards for testing
- To provide understanding on testing of packaging materials

UNIT I SELECTION CRITERIA FOR PACKAGING MATERIALS 9

Introduction to plastics packaging: functions of packaging, Types of packages, advantages of plastic packaging, special requirements of food and medical packaging,. Packaging as a system: Elements, approach, package, design, relation criteria for packaging materials, packaging equipment checklist, Major packaging plastics Introduction - PE, PP, PS, PVC, polyesters, PVA, EVA, PA, PC, ionomers & fluoro polymers

UNIT II CONVERSION PROCESS FOR PACKAGING MATERIALS 9

Conversion process - Compression & transfer for moulding, Injection moulding, Blow moulding, Extrusion, roto moulding, thermoforming. Lamination: wet lamination, dry lamination, heat or thermal lamination, extrusion lamination, hot melt or wax lamination, metallizing, Shrink wrapping, Pallet & stretch wrapping. Printing processes such as letter press, flexography, lithography, Gravure, silk screen, ink jet printing, hot die stamping and gold blocking

UNIT III PROCESS FOR FLEXIBLE PACKAGING 9

Extrusion, film and flexible packaging - co extrusion (cast film & sheet, Blown film, Multi layer film & sheet coatings, coextrusions laminations, , pouching, sealing (heat sealing, pressure sealing, adhesive sealing, solvent sealing and adhesive sealing,, evaluation of seals in flexible packages, advantages of flexible packaging - flexible packaging products.

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, plastic pallets, drums , shipping containers. Plastic Foams – Polyolefin foams, Polyurethane, Polystyrene and bio-based foams.

UNIT V TESTING OF PLASTIC PACKAGING 9

Evaluation and Testing of Plastics Packages: Introduction, general test methods, heavy duty packages, testing of blown moulded containers, laminates, stack load test, drop test, vibration test unusual test methods, testing of flexible plastic films, Barrier Properties –Oxygen transmission, Water vapour transmission rate migration;

Chemical resistance

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 : Select suitable polymer material for packaging

CO2 : Select the suitable technology for manufacturing of a specific type of packaging

CO3 : Select the different techniques for flexible packaging

CO4 : Perform various tests for evaluating the properties of rigid packaging

CO5 : Identify the suitable test method for predicting product performance and to analyze the failures in packaging.

TEXT BOOKS:

1. Seleke.E.M., 1997. *Understanding Plastic Packaging Technology.* Hanser publications.
2. Altalye. A.S., 1992. *Plastics in Packaging*, Tata McGraw-Hill publishing Co. Ltd, New Delhi.
3. Walter Soroka., 2002. *Fundamentals of packaging technology*, 3rd Edition, Institute of packaging professionals.
4. A.S. Athayle, “Handbook of packaging plastics”, Multi-Tech publishing co, First edition, 1999.

REFERENCES:

1. Selke. S.E.M., 2010. *Plastics Packaging – Properties, Processing and Applications.* John Culter.
2. Hannay. F., 2002. *Rigid Plastics Packaging* – Materials, Processes And Applications, Rapra Publications.
3. Paine. F.A., 1967. *Fundamentals of Packaging Technology*, Blackie & Sons Publication.
4. Barnetson., 1996. *Plastics Materials for Packaging*, Rapra Publications.

PT1734	POLYMER STRUCTURE AND PROPERTY RELATIONSHIP	L	T	P	C
		3	0	0	3

OBJECTIVES:

To enable the students to understand

- The structure of polymers and prediction of polymer properties
- The relationship between polymer structure and properties such as mechanical,
  thermal, electrical, optical and chemical properties

UNIT I STRUCTURE AND PROPERTIES OF POLYMERS 9

Linear, branched, crosslinked, and network polymers-Homochain and hetero atomic chain polymers - Copolymers and its types- Linear and cyclic arrangement - Prediction of polymer properties, group contribution techniques, topological techniques- Volumetric properties - molar volume, density, Van der Waals volume - Coefficient of linear thermal expansion and volumetric thermal expansion - Pressure volume temperature (PVT) relationship

UNIT II MECHANICAL PROPERTIES 9

Stress-strain properties of polymers - Effect of polymer structure on modulus of elasticity, tensile strength, flexural strength, impact strength, fracture toughness - Crazing in glassy polymers - Ductile brittle transition. Effect of additives on mechanical properties of polymers - Creep, stress relaxation, and fatigue

UNIT III THERMODYNAMIC AND TRANSITION PROPERTIES 9

Transition temperature in polymers, glass transition (Tg), melt transition (Tm), relationship between Tg and Tm - upper and lower glass transition, Prediction of TC, Tg and Tm of polymers by group contributions.

Calorimetric properties - Heat capacity, specific heat, latent heat of crystallization and fusion, enthalpy and entropy.

UNIT IV ELECTRICAL AND OPTICAL PROPERTIES 9

Effect of polymer structure on dielectric constant, dissipation factor, and loss factor - effect of frequency of voltage and temperature on dielectric properties - Prediction of molar polarization and effective dipole moment. Effect of additives - Factors affecting the electrical conductivity of polymers.

Optical properties - Effect of polymer structure on optical properties - clarity, transparency, haze, transmittance, absorbance, reflectance, and gloss - volume & surface resistivity, arc resistance.

UNIT V CHEMICAL PROPERTIES 9

Cohesive energy, cohesive energy density, solubility parameter, determination of solubility parameter of polymers - Prediction of solubility parameter – Effect of polymer structure on solubility in solvents and oils - Influence of structure in prediction of flame retardancy, water repellency - Chemical resistance of polymers - Polymer toxicity.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 : Apply group contribution method to compute volumetric properties

CO2 : Explain the effect of molecular structure on mechanical and electrical properties of polymers

CO3 : Predict thermal/ calorimetric properties and explain the factors affecting them;

CO4 : Gain the knowledge on structure effect the electrical and optical properties of polymers

CO5 : determine solvents for polymer using solubility parameter

TEXT BOOKS:

1. Van Krevelen. D.W., Hoftyzen. P.J., 2019. *Properties Of Polymer.* 4th Edition. Elsevier Scientific Publishing Company Amsterdam. Oxford - New York.
2. Jozef.Bicerano., 1995. *Prediction Of Polymer Properties*, Second Edition., Marcel Dekker Inc. New York.
3. Raymond. B., Seymour. Charles. E., Carraher., 1984. *Structure property relationships in Polymers.* Plenum press. NY.
4. Mark. J.E., 1996. *Physical Properties Of Polymers Hand Book.* Williston.

REFERENCES:

1. Seanor. D.A., 1982. *Electrical properties of polymers*. Academic press. New York.
2. Patrick Meares., *Polymers: structure and Bulk properties.* Van Nostrand. NY.
3. Margolis. J.M., 1985. *Engineering Thermoplastics Properties & Applications.* Marcel Dekker. New York.
4. Samuels. R.J., 1974. *Structured Polymer Properties*. John Wiley & Sons. New York.
5. Ku. C.C., Liepins.R., 1987. *Electrical Properties of Polymers.* Hanser Publications. Munich.

PT1735 POLYMERS IN CIVIL AND GEOPOLYMER

L	T	P	C
3	0	0	3

OBJECTIVES:

- To familiarize with the basic chemistry, structure of geopolymer formation
- To understand the fundamentals of Geopolymer composites (resins, pastes, mortars, concretes)
- To impart knowledge on the various types of Geosynthethic materials , properties of Geosythetics

UNIT I GEOPOLYMER MATERIALS 9

Constituents of geopolymers: Basic chemistry of geopolymeric source materials – silica, alumina, metakaolin, fly ash, GGBS, red mud, silica, pozzolonas etc., Physical and chemical characterisation of materials. Types of Geopolymers: alumino silicates-phosphates.

Geopolymeric structure: basic chemical structure of Geopolymer matrix, Binding action, Role of charge balancing counter ions in the basic molecular structure.

UNIT II GEOPOLYMER FORMULATIONS 9

Geopolymeric mix design: principle, basic concept, matrix formulation, paste, mortar, concrete, additives/admixtures, fibres. Reaction conditions-study of parameters: temperature curing (time duration, types, etc). Admixtures – properties, time of addition.

Factors affecting properties of Geopolymers : source material, Si/Al ratio, curing time, activator properties, ageing, addition of chemical additives, activator type and content, molar ratio, size and shape of specimens.

UNIT III MATRIX CHARACTERISATION 9

Characterisation of the hardened geopolymer matrix: mineralogy, XRD, FTIR, Microstructure: optical microscopy, SEM and NMR spectroscopy (1H and 29Si). NDT techniques – ultrasonic, rebound hammer, acoustic, electrical

UNIT IV APPLICATIONS OF GEOPOLYMERIC COMPOSITES 9

General introduction to different applications: Geopolymer cements/concretes: laying road, retrofitting and repairing. Geopolymeric precast products for housing – composites for specific applications: corrosion resistant-thermal/fire resistance-abrasion resistance. Applications in aircraft industry, environmental pollution control measures, performance evaluation equipment etc.

UNIT V GEOSYNTHETICS AN OVERVIEW 9

Historical Development - Types of Geosynthetics - Geotextiles – Geogrids Geonets--Geomembranes Physical properties : Mass per unit area – Thickness –Specific gravity; Hydraulic properties :Apparent open size – Permittivity –Transmissivity. Mechanical Properties : Uniaxial Tensile Strength – Burst and Puncture Strength – Soil Geosynthetic friction tests - Use of geosynthetics for filtration and drainage –Use of geosynthetics in roads –Improvement of bearing capacity–Geosynthetics in

landfills.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 **:** Describe the Constituents of geopolymers & Geopolymeric structure

CO2 **:** Develop the required Geopolymeric mix design and describe the affecting factors

CO3 **:** Identify different types of geosynthetics required based on their functions

CO4 **:** Analyze the properties of geosynthetics by lab testing method and its applications for various functions in Civil engineering.

CO5 **:** Apply the geosynthetics for bearing, filtration and drainage applicaitons

TEXT BOOKS:

1. Shukla, S.K. and Yin, J.H., 2006. *Fundamentals of geosynthetic engineering*. CRC Press.
2. Koerner, R.M., 2012. *Designing with Geosynthetics-; Vol2* (Vol. 2). Xlibris Corporation.
3. Davidovits, J., 2015. Geopolymer Chemistry and Applications. 4-th edition. *J. Davidovits.–Saint-Quentin, France*.
4. Provis, J.L. and Van Deventer, J.S.J. eds., 2009. *Geopolymers: structures, processing, properties and industrial applications*. Elsevier.

REFERENCES:

1. Babu, G.S., 2006. *An introduction to soil reinforcement and geosynthetics*. Universities Press.
2. Provis, J.L. and Van Deventer, J.S.J. eds., 2009. *Geopolymers: structures, processing, properties and industrial applications*. Elsevier.

ELECTIVE IV

		L	T	P	C
PT1736	**PAINTS AND SURFACE COATINGS**	3	0	0	3

OBJECTIVES:

- To learn the various polymer resins and synthesis
- Outline significance of fundamentals of paint science
- To know the various pigments and solvents for paints
- To know the various additives for paints
- To learn the particle size measurements and application of paints
- To know the mechanical properties of paints and coating

UNIT I ORGANIC FILM FORMERS 9

Fundamentals of paint science, reflection, refraction, diffraction, colour science, additive colour mixing, gloss, specular gloss, bloom gloss, surface uniformity, hiding power, chromaticity diagrams for colour measurements

Classification based on polymeric resin, emulsion, oil and alkyd paints, acrylic paints, epoxy coatings, polyurethanes,silicones, formaldehyde based resins, chlorinated rubbers, acrylics, hydrocarbon resins. Fluoropolymers, vinyl resins, Classification based on application. appliancefinishes,automotive finishes, coil coatings, can coatings, marine coatings, aircraft finishes.

UNIT II PIGMENTS FOR PAINTS 9

Paint components, pigments, pigment properties, different types, selection, dispersion and colour matching of pigments, solvents, different types, paint preparation, formulation, factors affecting pigment dispersion, preparation of pigment dispersion, manufacture, extenders, solvents, different types, solvent properties, oil, driers, resins, diluents, additives affecting viscosity, interfacial tension, chemical reactions, living micro organisms. Effects on viscosity – evaporation of solvent from cavity - Flashpoint – Toxicity, enamel, varnish.

UNIT III ADDITIVES FOR PAINTS 9

Anti-corrosive Pigments – Antifoams – Antisettling agent – Antiskinning agents – Can corrosive inhibitors – Dehydrates – Dispersion aids – Driers – Flash corrosion inhibitors – floating and flooding additives – Reodorants – UV absorbance.

Properties such as floating, silking, cratering, foaming, skinning, flame retardance, slipresistance and storage stability, surface cleaning methods, chemical conversion treatments,paint application, brushing, dip coating, flow coating, roller coating, spray painting, electro deposition, chemiphoretic deposition.

UNIT IV APPLICATIONS OF PAINTS AND COATINGS 9

Application of coating – Coating for building – Automotive parts – Automotive refinish paints -

General industrial paints – Painting of ships.

Mechanism of film formation, physical drying, oxidative drying, chemical drying, Adhesion

properties of coatings, factors affecting adhesive bond, thermodynamics of adhesion, testing of paint materials, destructive methods, nondestructive methods,

UNIT V MECHANICAL PROPERTIES OF PAINTS AND COATINGS 9

Factors affecting coating properties, film thickness, film density, internal stresses, pigment volume concentration (PVC), different methods used for film preparation, Mechanical properties and optical properties of coatings, ageing properties, effect of rheological behaviour on paint performance.Determination of mechanical properties of coating – Transient method – Dynamic method – Hardness test – Flexibility – Impact test – Acoustic emission – Durability test

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 :understand the various polymerization techniques for different resins

CO2 :specify the effects of pigments in paints

CO3 :classify the additives in paints.

CO4 :mention the impact of the particle sizing methods and various application of coatings

CO5 explain the mechanical properties of paints and coating

TEXT BOOKS:

1. LambourneR and Strivens,T.A2nd Edition1993"*Paint and Surface Coating: Theory and Practice",*, William Andrew Publishing.
2. Arthur.A.Traction, 2007"*Coatings materials and surface coatings",* CRC Press,.
3. Rodger Talbert, 2008"*Paint Technology Handbook*", CRC Press, London,

REFERENCES:

1. Swaraj Paul, 1996 *Surface coating: Science and Technology*, Wiley.
2. R. Lambourne.R 1987*Paint and Surface Coatings-Theory and Practice*.
3. Lambourne and Strivens,1999 *Paint and Surface Coatings*, Elsevier.
4. Z. Wicks et al,2007*Organic Coatings Science and Technology*, John Wiley & Sons.
5. Turner,2014*Introduction to Paint Chemistry and Principles of Paint Technology*, Springer.
6. Lewis, P.A 1988 *Pigment Handbook: Properties and economics*, Wiley.

PT 1737 POLYMERS FOR AEROSPACE APPLICATIONS L T P C

3 0 0 3

OBJECTIVES:

- To impart the knowledge of various types resins used for the manufacturing of air craft parts.
- To understand the various types of fiber materials and its applications for making Composites.
- To understand the knowledge of various manufacturing methods for making aircraft composites.
- To impart the knowledge by incorporating carbon nanotubes for aerospace applications.

UNIT I AERO SPACE GRADE POLYMERS - THERMOSET 9

Epoxies - diglycidylether of bisphenol - A resins, epoxy - novalacs, cycloaliphatic epoxies, thermoset polyurathenes - Thermoset polyimides - Bismaleimides (BMIs) - Cyanate esters (CEs) – Benzoxazines - Phthalonitriles.

UNIT II AERO SPACE GRADE POLYMERS - THERMOPLASTIC 9

Polyetheretherketone (PEEK) - Polyphenylsulfone (PPSU) - Polyetherimide (PEI) - Polyetherketoneketone (PEKK) - Polybenzimidazole (PBI) - Polyphenylene sulfide (PPS)

UNIT III FIBERS FOR AEROSPACE APPLICATIONS 9

Carbon fibres - precursors and production, properties; carbon/carbon composites-production, properties and applications; Sic fibre - Sic/Sic composites - Boron Fibre – Graphite Fibre - Ceramic Fibres.

UNIT IV MANUFACTURING OF COMPOSITES IN AEROSPACE 9

Contact moulding, compression moulding, vacuum bag/autoclave moulding, rotational moulding, resin transfer moulding (RTM), tape wrapping, filament winding, pultrusion, expanding bladder moulding.

UNIT V CARBON NANO TUBES IN AEROSPACE 9

Carbon nanotube (CNT), structure of CNT, synthesis of CNT, electronic, vibrational, mechanical and optical properties of CNT; applications of CNT.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 **:** Demonstrate different types of thermoset resins used for the manufacture of aircraft parts.

CO2 **:** Demonstrate different types of thermo plastic resins used for the manufacture of aircraft parts.

CO3 **:** Differentiate the Carbon and SIC synthetic fibres utilized for aerospace applications.

CO4 **:** Apply various manufacturing methods for producing aircraft parts.

CO5 **:** Implement Carbon Nano Tubes In Aerospace Apllications.

TEXT BOOKS:

1. Lubin, G., 2013. *Handbook of composites*. Springer Science & Business Media.
2. Peters, S.T. ed., 2013. *Handbook of composites*. Springer Science & Business Media.
3. Zhang, S. and Zhao, D. eds., 2012. *Aerospace materials handbook*. CrC Press.

REFERENCES:

1. Jawaid, M. and Thariq, M. eds., 2018. *Sustainable Composites for Aerospace Applications*. Woodhead publishing.
2. Irving, P.E. and Soutis, C. eds., 2019. *Polymer composites in the aerospace industry*. Woodhead Publishing.
3. Cantor, B., Assender, H. and Grant, P. eds., 2015. *Aerospace materials*. CRC Press.
4. Gao, F. ed., 2012. *Advances in polymer nanocomposites: Types and applications*. Elsevier.
5. Mouritz, A.P., 2012. *Introduction to aerospace materials*. Elsevier.

PT1738 PROCESS INSTRUMENTATION FOR POLYMER L T P C

TECHNOLOGIST **3 0 0 3**

OBJECTIVES:

- To learn the basic concepts of measurements system and transducers
- To understand the basics knowledge on temperature, pressure measuring devices.

  To acquire the knowledge on the flow measurement and vibration measurement devices .

UNIT I MEASUREMENT AND MEASUREMENT SYSTEM 9

Introduction, Significance of measurements, Methods of measurements ,Primary, Secondary and Tertiary Measurements, Classification of instruments, Function of instruments and measurement system, Application of measurement system, Elements for generalised measurement system, Errors -Types of Error, Systematic Errors.

UNIT II TRANSDUCERS 9

Transducers, Electrical Transducers, classification of transducers, characteristic and choice of transducers , factors influencing the transducers, potentiometers LVDT, RVDT, capacitive transducers. optical transducers

UNIT III TEMPERATURE MEASUREMENT DEVICES 9

Classification of temperature measuring device ,Measurement of Resistance Thermometer, Themistor, Thermocouple, Radiation Pyrometer, Principle used for Radiation Temperature Measuring Device, Total Radiation Pyrometer, Infrared Pyrometer, Optical Pyrometer

UNIT IV PRESSURE MEASUREMENT DEVICES 9

Types of pressure measurement device, manometers, types of manometer, bourdon tube bellow, diaphragm, McLeod gauge, Knudsen gauge, thermal conductivity of gauge , calibration of pressure measuring using dead weight tester.

UNIT V FLOW MEASUREMENT AND VIBRATION MEASUREMENT DEVICES 9

Flow through nozzle ,Electromagnetic flow meter , hot wire anemometer, hot film transducer, turbine flow meter , vortex meter, laser Doppler anemometer, measurement of angular velocity –mechanical tachometer and electrical tachometer.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 **:** Discuss the general concept of measurements and measurement system

CO2 **:** Classify the types of transducers and its functions.

CO3 **:** Express the different temperature measuring devices and its working principles.

CO4 **:** Demonstrate the pressure measuring device working principle , and applications.

CO5 : Construct the flow measuring devices and tachometers

TEXT BOOKS:

1. Sawhney, A.K. and Sawhney, P., 1995. *A course in mechanical measurements and instrumentation* (Vol. 3, p. 12). Dhanpat Rai, New Delhi.
2. Riley, W.F., McConnell, K.G., Dally, J.W., Dally, J.W. and Dally, J.W., 1993. *Instrumentation for engineering measurements*. Wiley.
3. Sirohi, R.S. and Krishna, H.R., 1991. *Mechanical measurements*. New Age International.

REFERENCES:

1. Ghosh, A.K., 2012. *Introduction to measurements and instrumentation*. PHI Learning Pvt. Ltd..
2. Klaassen, K.B., 1996. *Electronic measurement and instrumentation*. Cambridge University Press.
3. Morris, A.S. and Langari, R., 2012. *Measurement and instrumentation: theory and application*. Academic Press.
4. Rajput, R.K., 2009. *Mechanical Measurements & Instrumentation*. SK Kataria and Sons.
5. Purkait, P., 2013. *Electrical and electronics measurements and instrumentation*. McGraw-Hill Education.
6. Miller, H.B., 1977. Acoustical measurements and instrumentation. *The Journal of the Acoustical Society of America*, *61*(2), pp.274-282.
7. Kishore, K.L., 2009. *Electronic Measurements and Instrumentation*. Pearson Education India.

PT1739 SPECIALITY ELASTOMERS L T P C

3 0 0 3

OBJECTIVES:

To impart knowledge on manufacturing, compounding of various specialty elastomers

To acquire knowledge on processing and curing of various specialty elastomers

To provide exposure on various applications of specialty elastomers

UNIT I SPECIALITY RUBBER AND THEIR COPOLYMERS 9

Introduction of speciality Rubbers - Silicones (Q) - Introduction, Manufacture - Structure and its influence on properties - Compounding - Fabrication - Curing - General properties - Applications - Copolymers - PMQ, PVLQ, FMQ, FVMQ - Silicones Rubber for medical use

UNIT II CHLORO AND FLUORO ELASTOMERS 9

Chlorosulphonated polyethylene - Introduction - Manufacture - Structure and its influence on properties - Compounding - Curing - Properties - Applications Epichlorohydrin - (CO, ECO, ETIR)- Introduction - Manufacture - Structure and its influence on properties - Compounding and Curing-Properties and application Fluoro Elastomers (FKM) - Introduction - Manufacture - Structure and its influence on properties - Compounding - Curing - Properties and applications

UNIT III POLYSULPHIDE AND TPU 9

Polysulphides (TM) - Introduction, Manufacture - Cross linked Polyethylene (XLPE) – Polyurethane Rubbers - Introduction Manufacture - Structure and its influence on properties - Compounding - Curing - Properties and applications. Thermoplastic Polyurethanes - Introduction - Manufacture - Structure and its influence on Properties - Compounding - Curing - Properties and applications

UNIT IV ACM and THEIR COPOLYMERS 9

Acrylic Rubber (ACM), Ethylene acrylic copolymers, Introduction, Manufacture- Structure and its influence on Properties - Compounding - Curing - Properties and applications Ethylene Vinyl Acetate - Copolymer - Introduction, Manufacture - Structure and its influence on Properties - Compounding - Curing - Properties and applications

UNIT V CHLORONATED PE AND EPDM 9

Chlorinated Polyethylene - Introduction - Manufacture - Structure and its influence on Properties - Compounding - Curing - Properties and applications. EPM, EDPM - Introduction, Manufacture - Structure and its influence on Properties - Compounding - Curing - Properties and applications**.**

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 **:** State the fabrication, curing and properties of speciality rubbers and copolymers

CO2 : Familiarize the chloro and fluro elastomer used in special application

CO3 : Apply the knowledge on Structure and its influence on properties of polysulphide and TPU.

CO4 : Demonstrate the manufacturing and applications of ACM speciality polymer and its types

CO5 : Apply the compounding and curing characteristics for speciality rubbers like CPE and EPDM

TEXT BOOKS:

1. Hoffmann., 1989., *Rubber Technology Hand Book*, Hanser Publishers Munich.
2. Anil. K., Bhowmick, & Howard. L. Stephens., 1988., *Hand Book of Elastomers, New Development & Technology,* Marcel Decker Inc., New York,

REFERENCES:

1. Stoyko Fakirov, 2006., *Handbook of Condensation Thermoplastic Elastomers.,* John Wiley & Sons.

PT1740 TYRES AND TUBES TECHNOLOGY L T P C

3 0 0 3

OBJECTIVES:

- To make the students to understand the role of rubber in tyre.
- To acquire knowledge on cord reinforced rubber in tyre.
- To familiar in tyre manufacturing and retreading processes
- To provide understanding on tyre testing

UNIT I TYRE COMPONENTS AND STRUCTURE 9

Tyres – Function – Construction – Basic tyre design-Tyre Components and their functions, Tyre Materials, Tyre Nomenclature and Structural Dimensions, Classification of tyres based on applications and its requirements. Tubeless Tyre-Function, Construction, Materials and advantages

UNIT II TYRE CORD REINFORCEMENTS 9

Tyre cords – Physical Properties of tyre-cords- Rayon, Nylon, Polyester, Fibreglass, Aramid, Steel Wire-Cord Processing – Heat Treatment, Adhesive treatment, Bonding systems, Rubber to Cord Mechanism, Tyre Cord Construction, Evaluation of adhesive systems.

UNIT III TYRE COMPOUNDING AND MECHANICS 9

tyre compound and fundamental properties –compound development – raw materials for compounding- different tyre components – designing the compound matrix for the reinforced composite

Mechanics of rubber – cord-rubber composite and its properties, failure mechanism of cord reinforced rubbers composites. Inflation pressure – contact area, tyre deflections – design factors and principles. Rolling resistance, friction, mechanical loss on tyre behaviour

UNIT IV TYRE AND TUBE MANUFACTURING 9

Tyre manufacturing – tyre building – green tyre – curing methods – post curing - inflation – finishing. –Retreading – criteria – methods of retreading.

Tubes: Principles of tube design – manufacturing of tubes by extrusion, valve jamming, inflation & curing in presses, tube testing

UNIT V TYRE TESTING AND RECYCLING 9

Tyre Testing – Destructive and Non-destructive Testing of Tyres, Plunger Tests (Breaking energy), Pulley wheel test Field Tract Testing – Braking, Acceleration, mileage, Regulations, Tyre Labelling.

Recycling of rubber vulcanizate –use of recycled rubber

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 : describe the components and classification of tyres

CO2 : Select the reinforcement with respect to tyre cord

CO3 : choose the suitable compounding ingredients for tyre manufacturing

CO4 : Demonstrate the tyre and tube manufacturing process

CO5 : suggest a suitable destructive and non-destructive testing method of tyre

TEXT BOOKS:

1. Tom French., 1989., *Tyre Technology*, Adam Hilger.
2. James E. Mark, & Burak. Erman., 2005., S*cience and Technology of Rubber.*, Academic Press.

REFERENCES:

1. Ridha. R.A., & Theves. M., 1997 ., *Advances in tyre mechanics*., Rapra Technology Limited.
2. Bhowmick. A.K., Hall. M.M., &. Benaney. H.A., 1994., *Rubber Products Manufacturing Technology*., Marcel Dekker Inc, New York.

OPEN ELECTIVE II

OPT153	FUNDAMENTALS OF PLASTIC PACKAGING	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To make the student acquire knowledge on plastic packaging.
- To provide exposure on packaging of plastics
- To impart a thorough understanding of process of packaging.
- To provide knowledge on properties of packaging materials.
- To facilitate the students to understand the use of polymers for various applications.

UNIT I INTRODUCTION & RAW MATERIAL SELECTION CRITERIA 9

INTRODUCTION : definition of packaging as an integral part of production & marketing. Materials used, Advantages, limitations of various plastics like PE, PP, PVC, PS, POLYESTER, NYLON, EVA COPOLYMER, EVOH, PC, PVDC.

UNIT II CONVERSION PROCESSES-I 9

Injection moulding- containers, closures, containers with safety closures, small size containers. Extrusion process- Mono layer, multi layer, shrink, oriented films, cast, coating films, tapes, woven sacks, aluminium foil, laminations, sheet, tubes & profiles, twist wrap film, plasma barrier coating.

UNIT III CONVERSION PROCESSES-II 9

Blow molding process- composite containers, composite drums, small hollow containers , medical & pharmaceutical bottles, stretch blow moulding.
Foam moulding process – expanded polyethylene, poly styrene, structural & decorative foams. Rotary thermo forming, Batch & continuous thermo forming, Compression Moulding, Transfer moulding

UNIT IV FABRICATION & DECORATIVE TECHNIQUES 9

Cutting, sealing, welding, adhesive bonding. Printing, metallising, embossing, labeling, painting, lacquring, foil in lay moulding, hot stamping, Inmould decoration

UNIT V TESTING OF PLASTICS PACKAGES 9

Introduction; General test methods, Heavy duty packages, laminates, drop tests, stack test, load test, vibration test, Testing of flexible films, Indian standard for food containers

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 : Attain the basic knowledge on plastic packaging materials

CO2 : Demonstrate the conversion processes of packaging

CO3 : Develop the capacity of packaging polymers

CO4 : Analyze the packaging plastics by various techniques

CO5 : Identify the use of packaging plastics for various applications

TEXT BOOKS:

1. O'Hanlon, J.F., 2005. *A user's guide to vacuum technology*. John Wiley & Sons.
2. Mark, J.E. ed., 2009. *Polymer data handbook* (Vol. 2). New York: Oxford university press.
3. Briston, J., 1992. *Advances in Plastics Packaging Technology*. Pira International.

REFERENCES:

1. Robillard, J., Ralston, C. and Walden, G., Procter and Gamble Co, 2006. *Packages*. U.S. Patent Application 11/435,526.
2. Farmer, N. ed., 2013. *Trends in packaging of food, beverages and other fast-moving consumer goods (FMCG): markets, materials and technologies*. Elsevier.

OPT154 INTRODUCTION TO ELASTOMER TECHNOLOGY L T P C

3 0 0 3

OBJECTIVES:

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

UNIT I FUNDAMENTALS OF RUBBERS 9

Basics*:* Criteria for a polymer to behave as a rubber – structure vsTg, 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 NATURAL AND SYNTHETIC RUBBER 9

***Natural rubbers*:** Natural rubber latex, tapping – Conversion to dry rubber – Properties, grading and specifications of NR .

Synthetic rubbers: SBR: preparation, types, properties and applications– BR: polymerization, properties and applications – IR: Manufacture, properties and applications.

UNIT III ELASTOMER COMPOUNDING 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.

UNIT IV ELASTOMER PRODUCTS AND MANUFACTURING PRACTICES 9

Manufacturing methods of Belting and hoses, Sports Goods - Tennis Balls, Latex Products –Dipped goods- rubber band, Gloves, balloon - Manufacturing of Latex Foam -Rubber thread,

Good manufacturing practices - Effluent- Control and Treatment- Safety in rubber industry

UNIT V ELASTOMER RECYCLING 9

Tyre size reduction – Application of ground Rubber crumb – Filler – Bound Rubber products – Thermoplastics binder – Civil engineering applications – Surface treated crumb rubber – applications – Rubber reclaiming and devulcanization scrap rubber and fuel source (Tyre derived fuel TDF) – Pyrolysis.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 **:** Apply the solution for behavioral changes of elastomer based on the structure

CO2 : Select the suitable natural and synthetic rubber materials for applicaitokns

CO3 : Select the elastomer compound for the elastomer product.

CO4 : Choose the suitable manufacturing process for sports goods and latex products.

CO5 : Solve the recycling problems for elastomer.

TEXT BOOKS:

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

REFERENCES:

1. Martin, J.M.,and.Smith, W.K., 2004. *Handbook of Rubber Technology*. Vol. 1 & 2, CBS Publishers & Distributors.
2. Maurice Morton., 1987. *Rubber Technology*, Van Nostrand Reinhold.

OPT161	INTROUDCTION TO 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 natural polymers
- To impart knowledge about preparation , properties and application of synthetic polymers
- To provide exposure about polymerization methods
- To develop an understanding of molecular weight and solubility of macromolecules.

UNIT I INTRODUCTION TO POLYMERS 9

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

UNIT II NATURAL & INORGANIC POLYMERS 9

Natural Polymers: Chemical & Physical structure, properties, source, applications of polymers such as cellulose, lignin, starch, rosin, shellac, cellulose acetate, butyrate and nitrate – ethyl cellulose – carboxymethyl cellulos. etc

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

UNIT III SYNTHETIC POLYMERS 9

Raw material for synthetic polymers: Manufacturing of various fractions of crude petroleum important for polymer industry for Raw Materials such as ethylene, propylene, butadiene etc. and Brief idea of preparation, properties and application of polyethylene, polypropylene, polystyrene, polyvinyl chloride,

Novolac and resol.

UNIT IV POLYMERIZATION MECHANISM 9

Kinetics and mechanism of free radical, cationic, anionic and coordination polymerization - stereo regular polymerization– living polymers comparison of radical cationic and anionic polymerizations. Polycondensation polymerization- and Copolymerization.

UNIT V MOLECULAR WEIGHT 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.

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.

TEXT BOOKS:

1. Billmeyer, F.W., 1984. *Textbook of polymer science*. John Wiley & Sons.
2. Odian, G., 2004. *Principles of polymerization*. John Wiley & Sons

REFERENCES:

1. Bhatnagar,M.S., 2007, *A Text Book of Polymers (Chemistry and Technology of Polymers), Vol I, II & III,* S.Chand and Company.
2. Gowarikar V.R.,2015. *Polymer Science*, New Age International Pvt. Ltd
3. Carraher C E,2017., *Introduction to Polymer Chemistry*, CRC Press.
4. Ravie, A. 2012. *Principles of Polymer Chemistry,* Springer-Verlag.
5. Peacock, A.J. and Calhoun, A., 2012. *Polymer Chemistry: Properties and Application*. Carl Hanser Verlag GmbH Co KG
6. Fried; J. R.,2003, *Polymer Science and Technology,* Prentice-Hall of India Pvt. Ltd.,
7. Young, R.J. and Lovell, P.A., 2011. *Introduction to polymers*. CRC press
8. Ghosh, P., 1990. *Polymer science and technology*. Tata McGraw-Hill Education.

OPT162	INTRODUCTION TO PRODUCT	L	T	P	C

TESTING **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 Structural evaluation of polymers 9

Principles, theories and applications to polymeric systems with suitable illustration of the following techniques: Fourier transform infrared spectrometry, Ultraviolet - visible spectrometry, Nuclear magnetic resonance spectrometry, Mass spectrometry, X-ray diffraction spectrometry, Gas chromatography.

UNIT II Thermal properties of polymers 9

Glass transition temperature, melting temperature, heat distortion temperature, etc. Sample preparation, standardization, conditioning of sample, processability test, dynamic mechanical analysis, melt flow rate, Vicat softening temperature. Study of a dilatometer. Study of thermo-chemical analysis and differential scanning calorimeter and their applications to polymers with suitable examples

UNIT III Electrical properties 9

Surface volume resistivity, Breakdown voltage, Arc resistance, Tan Delta, etc. The theory behind these phenomena, application to polymers and evaluation.

UNIT IV Mechanical properties 9

Their principles and applications to polymers, Tensile strength, flexural strength, impact resistance, percentage elongation, Griffin theory, tear test, fatigue and wear, hardness, compressive strength time dependant properties like creep, stress, relaxation, etc

UNIT V Environmental resistance & Optical properties 9

Environmental resistance: Stress cracking, effect of weathering, biological degradation, fire, radiation staining.

Optical properties: Refractive index, gloss, colour matching, haze

Fire test: Ignition of flame and spread, limiting oxygen index, rate of heat release, smoke toxicity test

Adhesion test: Peel test, tension test, shear test.

Microscopy: Scanning electron microscopy, travelling electron microscope.

Identification of polymers using chemical methods

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1	:	Attain the basic knowledge of polymers structural evolution
CO2	:	Demonstrate thermal properties of various polymers
CO3	:	Interpretation the electrical properties of polymers
CO4	:	Analyze the various polymers mechanical properties
CO5	:	Identify the environment needs and test polymers for various applications

TEXT BOOKS:

1. Lobo, H. and Bonilla, J.V., 2003. *General introduction to plastics analysis*. PLASTICS ENGINEERING-NEW YORK-, *68*, pp.1-42.
2. Brown, R. ed., 1999. *Handbook of polymer testing: physical methods*. CRC press.

REFERENCES:

1. Shah, V., 1998. *Handbook of plastics testing technology*.
2. Ives, G.C., Mead, J.A. and Riley, M.M., 1971. *Handbook of plastics test methods*.

OPT163	POLYMER NANOCOMPOSITES	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To understand the basics and chemistry of nano size materials and their synthesis,characterization and applications.
- To equip with the knowledge on the processing of polymer nanocomposites.
- To study the various methods employed for the dispersion of nanomaterials in polymers.
- To provide knowledge in nanocomposite technology

UNIT I INTRODUCTION TO POLYMER NANOCOMPOSITES 9

Introduction to polymer nanocomposites – layered silicates – carbon nanotubes – inorganic nanofillers – polymer filler interfaces – modification of interfaces – ceramic/polymer nanocomposites – metal/polymer nanocomposites – natural nano biocomposites

UNIT II POLYMER - LAYERED SILICATE NANOCOMPOSITES 9

Polymer-layered silicate nanocomposites: types of nanoclays – thermoplastics and thermosets and elastomer matrices. Preparation of polymer-layered silicate nanocomposites – solution – melt mixing – latex mixing methods – techniques for achieving dispersion of nanofillers – intercalation and exfoliation

UNIT III POLYMER - CNT NANOCOMPOSITES 9

Carbon nanotube (CNT) – reinforced polymer nanocomposites: structure of carbon nanotubes – dispersion properties of CNT nanocomposites – interfacial bonding properties – mechanical properties and conductivity of nanotube-polymer nanocomposites.

UNIT IV PROCESSING OF POLYMER NANOCOMPOSITE 9

Processing of polymer nanocomposites – direct mixing – melt mixing – solution mixing – In-situ polymerization – In-situ particle processing – ceramic/polymer composites – metal/polymer nanocomposites – natural nanocomposites

UNIT V APPLICATIONS OF POLYMER NANOCOMPOSITES 9

Applications of polymer nanocomposites: automobiles – aerospace – injection moulded products – coatings and adhesives – fire retardants – packaging materials – microelectronic packaging – dielectrics – drug delivery – membranes – medical devices and consumer goods

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 **:** Explain the basic principles and types of polymer nanocomposites.

CO2 **:** Select the appropriate nanofillers for the synthesis of nanocomposites with a novel polymer to achieve synergistic properties

CO3 **:** Analyze and characterize polymer nanocomposites

CO4 **:** Select appropriate techniques for processing of polymer nanocomposites.

CO5 **:** Gain knowledge applications of polymer nanocomposites.

TEXT BOOKS:

1. Chaudhery Mustansar Hussain., Ajay Kumar Mishra., 2018. *New Polymer Nanocomposites for Environmental Remediation*. Elsevier publication.
2. Ahmad Fauzi Ismail., Pei Sean Goh., 2018. *Carbon-based Polymer Nanocomposites for Environmental and Energy Applications*. Elsevier publication.
3. Koo.H., 2016. *Fundamentals, Properties, and Applications of Polymer Nanocomposites*.
4. Vikas Mittal., 2014. *Polymer Nanocomposite Coatings*. Taylor and Francis group.
5 M. Ajayan. M., Schadler. L.S., Braun. P.V., 2003. *Nanocomposite Science and Technology*. WILEY-VCH Verlag GmbH.

REFERENCES:

1. Jyotishkumar Parameswaran Pillai. Nishar Hameed. Thomas Kurian. Yingfeng Yu. 2017. *Nanocomposite Materials: Synthesis, Properties and Applications.* Taylor and Francis group.
2. Aravind Dasari. Zhong-Zhen Yu. Yiu-Wing Mai. 2016. *Polymer Nanocomposites: Towards Multi-Functionality*. Springer.
3. Rakesh Gupta. K., Elliot Kennel., Kwang-Jea Kim., 2010. *Polymer Nanocomposites Handbook*. Taylor and Francis group.
4. Ramanan Krishnamoorti., Richard. A., Vaia., Washington. D.C., 2002. *Polymer nanocomposites: synthesis, characterization, and modeling.* American Chemical Society. Oxford University Press.
5 Hussain. F., .Hojjati. M., Okamoto. R.E., 2006. *Polymer matrix nanocomposites, processing, manufacturing, and application: An overview.* J. Comp. Mater.
6. Vikas Mittal., 2010. *Polymer Nanotube Nanocomposites.* John Wiley & Sons, New Jersey.

OPT164	POLYMERS PROCESSING TECHNOLOGY	L	T	P	C
		3	0	0	3

OBJECTIVES:

- To make the student acquire knowledge on polymers processing.
- To provide exposure on processing of different polymer products.
- To impart a thorough understanding of hollow and solid polymer products processing.
- To provide knowledge on various machine functions.
- To facilitate the students to understand the use of polymer products In various applications

UNIT I INJECTION MOULDING 9

Basic principles- Definition of terms-specifications-Types of machines used-parts and their functions. Injection moulding cycle-process variables and their effect on product quality. Common moulding defects, causes and remedies. Thermoset injection moulding –Machine description, parts –process parameters.

UNIT II EXTRUSION 9

Introduction-principles-classification of extruders, single screw & Twin screw extruder, specifications, screw nomenclature. Various extrusion methods and post extrusion systems like sizing, cooling, take-off, cutting etc., as related to film, pipe, sheet, wire and profile extrusions. Trouble shooting in extrusion line.

UNIT III COMPRESSION MOULDING 9

Introduction-principles-types of Machines, types of moulds. Compression moulding cycle, process variables and their effect on product quality. Common moulding defects, causes and remedies, advantages and disadvantages.

Transfer Moulding: Introduction-principles- moulding types. Common moulding defects, causes and remedies, advantages and disadvantages.

UNIT IV BLOW MOULDING 9

Introduction-principles-processes-Extrusion blow moulding –Injection blow moulding-stretch blow moulding- blow moulding of large containers-parison programming.

Rotational Moulding :Introduction-principles-process-machinary used- process parameters –merits and demerits

UNIT V CALENDERING 9

Introduction-calender roll arrangements-calendering process-process variables applications-merits and demerits.

Thermoforming: Introduction-various types of thermoforming process- process variables – applications –merits and demerits.

TOTAL: 45 PERIODS

OUTCOMES:

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

CO1 : Attain the basic knowledge on polymers processing

CO2 : Demonstrate processing of various polymer products

CO3 : Develop the new concepts in polymer products making

CO4 : Analyze the various products problems

CO5 : Identify the Causes and eliminate the problems in polymer processing

TEXT BOOKS:

1. Whisson, R.R., 1974. *Injection moulding—theory and practice:* Irvin I. Rubin John Wiley, New York, 1973, 672 pp. 12.50.
2. Athalye, A.S., 2007. *Special injection moulding processes*. POPULAR PLASTICS AND PACKAGING, 52(6), p.83.
3. De Zwart, J., 1971. *Methods of Processing Plastics- In Handbook of Precision Engineering* (pp. 3-57). Palgrave, London.
4. Lee, N.C., 2006. *Practical guide to blow moulding*. Smithers Rapra Publishing.

REFERENCES:

1. Frados, J., 1976. *Plastics engineering handbook of the Society of the Plastics Industry, inc*.
2. Chan, I.W., Pinfold, M., Kwong, C.K. and Szeto, W.H., 2011. *A review of research, commercial software packages and patents on family mould layout design automation and optimisation*. The International Journal of Advanced Manufacturing Technology, *57*(1-4), pp.23-47.