Appendix - V (G)

CURRICULUM FRAMEWORK AND SYLLABUS
(OUTCOME BASED EDUCATION)

M. TECH. (POLYMER TECHNOLOGY)
(with effect from the academic year 2024–25)

COCHIN UNIVERSITY OF SCIENCE & TECHNOLOGY

Kalamassery, Cochin - 682022 Kerala, India Phone: 0484 – 2575723

April 2024

Vision

The Department strives to develop a Centre of Excellence in Polymer Technology in the country by strengthening in-house infrastructure and taking up collaborative Research and Development in frontier areas.

Mission

As a Department we are committed to:

- Acquire state-of-the-art infrastructure and take up inter-disciplinary research in frontier areas.
- Achieve academic excellence in the field of Polymer Science and Rubber Technology through innovative teaching - learning processes.
- Prepare well-trained human resource in Polymer Science and Rubber Technology who can contribute positively to the developmental efforts of the Nation.
- Promote good academia - industry interaction.

Programme outcome

PO1.Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, techniques, skills, and modern tools of polymer Science and engineering to the solution of polymer engineering problems.

PO2.Problem Analysis: Identify, formulate, research literature, and analyze engineering problems related to Polymer Science and Engineering to arrive at substantiated conclusions using first principles of mathematics, natural, and engineering sciences.

PO3. Design/development of solutions: Design solutions for complex engineering problems and design system components, processes to meet the needs of public health and safety, and the cultural, societal, and environmental considerations in the field of Polymer Science and Rubber Technology.

PO4. Conduct investigations of complex Problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the **information to provide valid conclusions for broadly defined polymer science and engineering problems.**

PO5. Modern Tool Usage: Create, select and apply appropriate techniques, resources and modern engineering and IT tools including prediction and modeling to Polymer Science and Engineering activities with an understanding of the limitations.

PO6. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice related to Polymer Science and Engineering.

Admission and Regulations

The admissions to this programme is based on the GATE score. In case of non- availability of GATE qualified candidates, the selection will be done based on Departmental Admission Test (DAT). The notification for admission will be published during December/January.

The regulations in force is published by the University. The current regulation is available at https://cusat.ac.in/student/mtech-regulations.

M TECH POLYMER TECHNOLOGY

CURRICULUM

SEMESTER I

Course code	Subject	C/E	Hrs per week			Credit	Marks		
			L	T	P		CE	EE	Total
24–440–0101	Advanced Polymer Science	C	3	0	0	3	50	50	100
24–440–0102	Polymer Materials	C	3	0	0	3	50	50	100
24-440-0103	Advanced Polymer Product Design	C	3	0	0	3	50	50	100
24–440–0104	Research Methodology and IPR	C	2	0	0	2	50	50	100
24-440-012*	Prog. Elective I	E	3	0	0	3	50	50	100
24-440-013*	Audit course	A	2	0	0	0	–	100	100
24-440-011*	Lab 1 (Prog. Core based)	C	0	0	4	2	100	–	100
24-440-011*	Lab 2 (Elective based)	E	0	0	4	1	100	–	100
	Total					**17**	**450**	**350**	**800**

SEMESTER II

Course code	Subject	C/E	Hrs per week			Credit	Marks		
			L	T	P		CE	EE	Total
24–440–0201	Advanced Plastics processing	C	3	0	0	3	50	50	100
24–440–0202	Rubber Processing and Product Manufacture	C	3	0	0	3	50	50	100
24-440-0203	Advanced Tyre Technology	C	3	0	0	3	50	50	100
24-440-022*	Prog. Elective II	E	3	0	0	3	50	50	100
24-440-022*	Prog. Elective III	E	3	0	0	3	50	50	100
24-440-021*	Lab 3 (Prog. Core based)	C	0	0	4	2	100	–	100
24-440-021*	Lab 4 (Elective based)	E	0	0	4	1	100	–	100
24–440–0251	Minor Project with Seminar	C	0	0	2	2	100	–	100

	Total					20	550	250	800

SEMESTER III									
Course code	Subject	C/E	Hrs per week			Credit	Marks		
			L	T	P		CE	EE	Total
24-440-032*	Prog. Elective IV	E	3	0	0	3	50	50	100
24-440-036*	Open Elective	E	3	0	0	3	–	100	100
24–440–0341	Dissertation - I	C	0	0	20	10	–	100	100
	Total					**16**	**50**	**250**	**300**

SEMESTER IV									
Course code	Subject	C/E	Hrs per week			Credit	Marks		
			L	T	P		CE	EE	Total
24–440–0441	**Dissertation - II**	C	0	0	35	19		300	300
	Total					**19**		**300**	**300**
	GRAND TOTAL					**72**	**1050**	**1150**	**2200**

Programme Elective I	
24–440–0121	Polymers for packaging
24–440–0122	Advanced Polymer Rheology
24–440–0123	Characterisation and Testing Methods
Programme Elective II	
24–440–0221	Specialty polymers (I.E.)
24–440–0223	Advanced Polymer Nanocomposites (I.E.)
Programme Elective III	
24–440–0224	Mould and Die Design
24–440–0225	Polymers for Advanced Electrical and Electronics Applications
24–440–0226	Materials in Space Applications
Programme Elective IV	
24–440–0321	Adhesives and Surface Coatings
24–440–0322	Advanced Biomaterials for Medical Applications (I.E.)
24–440–0323	Modelling and Simulation
Lab 1: Labs - Core based (Sem I)	
24-440-0111	Advanced Polymer Science
Lab 2: Labs - Elective based (Sem I)	
24-440-0112	Polymers for packaging
24-440-0113	Advanced Polymer Rheology
24-440-0114	Characterisation and Testing Methods
Lab 3: Labs - Core based (Sem II)	
24-440-0211	Plastics and Rubber Processing
Lab 4: Labs - Elective based (Sem II)	
24-440-0212	Specialty polymers
24-440-0213	Advanced Polymer Nanocomposites
24-440-0214	Mould and Die Design
24-440-0215	Polymers for Advanced Electrical and Electronics Applications
24-440-0216	Materials in Space Applications

The **open elective** is to be taken from the courses offered **by NPTEL/ SWAYAM.**

Tentative list of online courses approved by DC. Further courses may be selected by students which need to be approved by the Department.

Open Elective Courses	
24-440-0361	Properties of Materials
24-440-0362	Biomedical Nanotechnology
24-440-0363	Technologies For Clean And Renewable Energy Production
24-440-0364	Environmental Quality modelling and Analysis
24-440-0365	Membrane Technology
24-440-0366	Chemical Process Safety
24-440-0367	Chemical Reaction Engineering
24-440-0368	Soft Nanotechnology
24-440-0369	Waste to Energy Conversion
24-440-0370	Environmental Degradation of Materials
24-440-0371	Rheology of Complex materials
24-440-0372	Environmental Engineering
24-440-0373	Municipal solid waste management
24-440-0374	Fundamentals of combustion for propulsion
24-440-0375	Medical Biomaterials
24-440-0376	Biomass Conversion and Biorefinery
24-440-0377	Materials Science and Engineering
24-440-0378	Organometallic Chemistry
24-440-0379	Polymer Reaction Engineering
24-440-0380	Pericyclic Reactions and Organic Photochemistry
24-440-0381	Physical and Electrochemical Characterizations in Chemical Engineering
24-440-0382	Nature and Properties of Materials
24-440-0383	Fundamentals of Materials Processing - Part 2

Audit courses	
24–440–0131	Constitution of India and environmental governance: administrative and adjudicatory process
24–440–0132	Principles of management
24–440–0133	Technical English for engineers
24–440–0134	Entrepreneurship and IP strategy
24–440–0135	Exploring Human Values: Visions of Happiness and Perfect Society
24–440–0136	Speaking Effectively
24–440–0137	Enhancing Soft Skill and Personality
24–440–0138	Plastic Waste Management
24–440–0139	Scanning Electron / Ion / Probe Microscopy in Materials Characterization
24–440–0140	Chemical Process control
24–440–0141	Introduction to programming
24–440–0142	Managing Intellectual Property in Universities
24–440–0143	Patent drafting for beginners
24–440–0144	Development Research Methods
24–440–0145	Entrepreneurs
24–440–0146	Polymer Assisted Abrasive Finishing Processes
24–440–0147	Science and Technology of Weft and Warp Knitting

YLLABUS

SEMESTER I

20-440-0101 Advanced Polymer Science

Course Outcome

On successful completion of the course, the students will be able to:

CO1:	Explain fundamentals of polymerisation reactions and predict composition of copolymers. (Analyse)
CO 2:	Understand the special synthesis routes for polymerisation.(Understand)
CO 3:	Comprehend the molecular motions based on kinetic and thermodynamic considerations.(Analyse)
CO 4:	Analyze polymer structure and properties based on molecular weight determination, spectroscopic, thermal and X-ray scattering techniques.(Analyze)
CO 5:	Get an insight in to the degradation of commercial polymers and the management of polymer wastes. (Analyse)

Mapping of course outcomes with program outcomes:
Level - Low (1), medium (2) and high (3)

Unit 1. Mechanistic aspects of polymerization–Basics of Polymerisation: Addition polymerisation: Free radical, Cationic and Anionic polymerisation; condensation polymerisation, Stereoregular polymerisation-monometallic and bimetallic; Copolymerisation: general characteristics, mechanisms, kinetics of copolymerization, composition of copolymers, block and graft copolymers.

Unit 2. Special synthesis routes– Cyclopolymerisation: general features, mechanism. Ring-opening polymerization, , Metathesis polymerisation: ring -opening metathesis polymerisation (ROMP). Living polymerization: atom -transfer-radical-polymerization (ATRP), reversible addition fragmentation chain transfer (RAFT).

Unit 3. Polymer Solutions–Thermodynamics of polymer solutions: dissolution of polymers, factors affecting dissolution and swelling, Flory - Huggins theory, enthalpy of mixing, cohesive energy density, solubility parameter,. Kinetic and thermodynamic considerations: step growth and chain growth mechanism under ideal and real conditions.

Unit 4. Characterization techniques– Molecular characterization of polymers– average molecular weight, molecular weight distribution, determination of molecular weight – end group analysis, colligative property measurement –Osmometry; light scattering, solution viscosity and gel permeation chromatography.

Spectroscopy techniques: Infra red, NMR, UV-visible. Thermal properties: differential scanning calorimetry, differential thermal analysis, thermogravimetry, dynamic mechanical analyzer. Microscopic techniques: optical and electron microscopy Crystallinity studies: density measurements, XRD.

Unit 5. Polymer Degradation and Stabilization–Principles of thermal, photo, oxidative and biodegradation in polymers. Methods/equipments used for monitoring the degradation in polymers. Mechanism of degradation of some commercial polymers. Biodegradation of polymers. Waste Management.

References

1 F.W. Billmeyer, A Text Book of Polymer Science, 3rd Edn., Wiley & Sons (2009).

2 Herman F. Mark (Ed.),Encyclopedia of Polymer Science and Engg., Vol 15, 4th Edn., Wiley & Sons (2014).

3 P.J.Flory, Principle of Polymer Chemistry, Cornell University Press (1986).

4 V. R. Gowariker, N. V. Viswanathan and J. Sreedhar,Polymer science, John Wiley & Sons (2010).

5 J.F.Rabek, Experimental methods in polymer chemistry, Wiley & Sons, Imprint:Academic Press (2012).

6 Hans-George-Elias, Macromolecules Vol.1, Plenum press, Springer (1986).

7 George Odion, Principles of Polymerization, 4th Edn., Wiley & Sons (2007).

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	3	3	3	2	2
CO 2	3	2	3	3	2	2
CO 3	2	2	2	2	2	2
CO 4	2	3	3	3	2	2
CO 5	3	3	3	2	2	2

References

1 F.W. Billmeyer, A Text Book of Polymer Science, 3rd Edn., Wiley & Sons (2009).

2 Herman F. Mark (Ed.),Encyclopedia of Polymer Science and Engg., Vol 15, 4th Edn., Wiley & Sons (2014).

3 P.J.Flory, Principle of Polymer Chemistry, Cornell University Press (1986).

4 V. R. Gowariker, N. V. Viswanathan and J. Sreedhar,Polymer science, John Wiley & Sons (2010).

5 J.F.Rabek, Experimental methods in polymer chemistry, Wiley & Sons, Imprint:Academic Press (2012).

6 Hans-George-Elias, Macromolecules Vol.1, Plenum press, Springer (1986).

7 George Odion, Principles of Polymerization, 4th Edn., Wiley & Sons (2007).

Revision- 40%

24-440-0102 Polymer Materials

Course outcome

On successful completion of the course, the students will be able to:

CO 1: Acquire in depth knowledge on different types of polymeric materials and general purpose rubbers. (Understand)

CO 2: Understand the structural property relations of different special purpose elastomeric materials and their applications. (Understand)

CO 3: Understand the structural property relations of different thermoplastic materials and their applications. (Understand)

CO 4: Acquire in depth knowledge on polyamides, polyesters and polyurethanes and their applications. (Understand)

CO 5: Understand the preparation and structural property relations of different thermoset materials and their applications. (Understand)

Unit 1. General Purpose Elastomeric materials – Introduction to manufacture, structure, properties and applications of styrene butadiene rubber (SBR), Natural rubber (NR), poly isoprene rubber (PIR), acrylonitrile-butadiene rubber (NBR) and polychloroprene rubber (CR). Comparison of different unsaturated rubbers (SBR, PIR, NBR, NR and CR).

Unit 2. Special Purpose Elastomeric Materials – Comparison with general purpose elastomeric materials, Introduction to manufacture, structure, properties and applications of butyl rubber (IIR), EPDM, EPM, hypalon, silicone and polyurethane rubbers. Comparison of these rubbers with unsaturated elastomers SBR, PIR, NBR, CR and NR with respect to structure and properties.

Unit 3. Thermoplastic and thermosetting behaviour of plastics. Thermoplastic Materials (poly olefins and Vinyl polymers) – Introduction to preparation, general properties and uses of important thermoplastics: polyethylenes (PE), polypropylene (PP), polyvinyl chloride (PVC), polyvinylidene chloride, polystyrene (PS).

Unit 4. Engineering thermoplastics and conducting polymers: Poly Amides and Polyesters Based Polymer Materials – Preparation, properties and uses of Nylon-6 and Nylon-66 and Kevlar. Important polyesters and polyurethanes in commercial applications. Manufacture, structure, properties and uses of polycarbonates, acetals resins, polyimides, PMMA. Introduction to

conducting polymers: Polyacetylene, Polyaniline, Polypyrrole, Polythiophene.

Unit 5. Thermosets – Manufacture, structure, curing, moulding powder, laminates, general properties and applications of phenolic resins (PF), urea formaldehyde (UF) and melamine formaldehyde (MF) resins and epoxy resins.

Reference

1. **Maurice Morton, Rubber Technology, 3rd Edn., Kluwer Academic Publishers (1999).**
2. **C.M. Blow, Rubber Technology and Manufacture, Butterworths (1982).**
3. **J. A Brydson, Plastic Materials: 7th Edn., Oxford Butterworths (1999).**
4. **Gilbert Marianne, Brydson's Plastics Materials, Edited: 8th Edn., Elsevier (2017).**
5. **D. C Blackly, Synthetic Rubbers, Applied Science Publishers (1983).**
6. **Ehrenstein Gottfried, Polymeric materials, Hanser Publishers (2001).**
7. **Natural Rubber and Agromanagement, Rubber Research institute of India (2000)**

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	2	2	2	2	2
CO 2	2	3	3	2	3	2
CO 3	2	2	3	2	3	2
CO 4	3	3	2	2	3	2
CO 5	2	2	2	2	2	2

Revision – 30%

24–440–0103 Advanced Polymer Products Design

Course Outcome

On successful completion of the course, the students will be able to:

CO 1:	Structure – property relationship and role of fillers in polymers. (Understand)
CO 2:	Design polymeric gears, bearings and PVC piping.(Apply)
CO 3:	Design O-ring and vibration dampers.(Apply)
CO 4:	Joining of plastics using ultrasound and snap fits (Understand)
CO 5:	Design of thermosets, metal plating of plastics, design of self-hinges. (Apply)

Unit 1. Structure and properties of polymers – Stress- strain behaviour, effect of fillers on properties of polymers. Creep and stress relaxation. Pseudoelastic design approach. Design of plastic beams.

Unit 2. Design of products I – Gears: materials, strength and durability, moulded v/s cut plastic gearing, inspection assembly and operation. Bearings: self-lubricated plastic materials, rubber bearing, type of bearings, designers check list. PVC piping: raw materials, pipe design, specification and test procedure, manufacturing process.

Unit 3. Design of products II – Elastomeric ring seals: basic configurations, design method, design consideration, static and dynamic seals. Vibration dampers: basic vibration damping relations, octave rule for damped systems, estimating damping in structures, controlling resonant peaks with damping, response of damped structures to shock.

Unit 4. Ultrasonic assembly of thermoplastics- theory, equipment, type of assembly, joint design for assembly, materials for ultrasonic welding. Snap fits and hinges: Design of cantilever snaps, assembly and disassembly, annular snap fits. Plastic hinges- design and production.

Unit 5. Thermoset part design- materials, general design recommendations for parting line, straight draw, undercuts, sharp corners, cross sectional areas, wall sections, taper, ribs, bosses, holes, threaded holes, surface flatness. Plating on plastics, the plating process, preparation for plating, electroless plating, electroplating, testing of electroplate, typical formulation of electroless plating and electroplating solutions.

References

1 Edward Miller, Plastics Products Design Handbook-Materials and Components, Part A, Marcel Dekker (1981).

2 Edward Miller, Plastics Products Design Handbook-Materials and Components, Part B, CRC Press (1983).

3 Paul F. Mastro, Plastics Product Design, Scrivener Publishing (2016)

4 P. K. Freekly, A.R. Payne, Theory and Practice of Engineering with Rubber, Applied Science (1978).

5 S. Levy, J. H. Dubois, Plastic Product Design Engineering Hand Book, 2nd Edn., Springer science (2012).

6 A.N. Gent (Ed.), Engineering with Rubber: How to Design Rubber Components, Hanser Pub. Inc.(2001).

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	3	3	2	2	2
CO 2	3	3	3	2	3	2
CO 3	3	3	2	2	3	2
CO 4	1	2	1	1	2	1
CO 5	1	1	1	1	1	1

Revision- 40%

24-440-0104 Research Methodology and IPR

Course Outcome
On successful completion of the course, the students will be able to:

CO1: Explain research process and research problem. (Understand)

CO 2: Understand the design of research. (Understand)

CO 3: Discuss the methods and techniques of data collection. (Understand)

CO 4: Explain the field work in research and data processing. (Understand)

CO 5: Understand different forms of IPR. (Understand)

Unit 1. Research – Definition, meaning, research as the application of scientific method. Importance of research. The Research Process and types of Research. Defining the Research Problem. Problem Formulation and Statement of Research.

Unit 2. Research Design – Details and applications of exploratory, descriptive, diagnostic/conclusive and experimental researches. Operational and Administrative structure for research. Sampling and Sampling Designs.

Unit 3. Methods & Techniques of data collection – Observational and other survey methods, development and designing of tools of data collection, measurement scales. Levels of measurement and questions of validity and reliability. Mean, Standard deviation, Normal distribution.

Unit 4. Fieldwork in research and data processing – Analysis and Interpretation of Data: univariate analysis, bivariate analysis of data-Correlation and Regression. Testing of hypothesis, parametric and non-parametric tests. Mathematical models.

Unit 5. Reporting of research – Graphical presentatation of data, types of reports, substance of reports, format of Report. Presentation of Reports.
IPR – Analysing and understanding the Interpretation of IP laws , need for protecting IP. Forms of IPR: copyright ,trademark ,patents, industrial designs, trade secrets , geographical

indications, application of different forms of IPR

References

1 Roger Bennett, Nitish De, Management Research: Guide for Institutions and Professionals, 3rd Edn., International Labour Office (1983).

2 Claire Selltiz,Marie Jahoda,Morton Deutsch,Stuart W. Cook. (Ed.) , Research methods in social relations,Methuen (1977).

3 Neil J.Salkind, Exploring Research, 9th Edn., Pearson Education (2016).

4 C.R.Kothari, Research Methodology: Methods and Techniques, New Age International (2004).

5 Taro Yamane, Statistics: an Introductory Analysis, 3rd Edn., Harper & Row (1973).

6 Richard I Levin, Statistics for Management, Pearson Education India (2011)

7 V. K. Ahuja, Law Relating to Intellectual Property Rights, 2nd Edn.,Lexis Nexis (2013).

8 Craig Allen Nard, Law of Intellectual Property, 2nd Edn., Aspen publishers(2008).

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	2	2	2	2	3
CO 2	2	2	3	2	2	3
CO 3	1	2	3	3	3	2
CO 4	2	3	2	2	2	3
CO 5	2	2	2	2	2	3

24-440-0111 Advanced Polymer Science

Course Outcome

On successful completion of the course, the students will be able to:

CO1: Identify the plastics and rubbers used in various unknown polymeric products.

CO2: Estimate molecular weight of polymers by different techniques.

CO3: Understand the various synthesis methods for the preparation of polymers

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	1	2	1	2
CO2	2	1	1	2	1	2
CO3	2	2	1	1	1	2

1. Identification of rubbers, plastics and thermoplastic elastomers -NR, SBR, PB, IR, IIR, EPDM, Hypalon, Thiokol, Silicone, CR, NBR, PE, PP, PS, PVC, PVA, PF, UF, MF, Polyester, SIS, SBS, SEBS, Hytrel.

2. Estimation of polymer molecular weights

   a) Viscometry

   b) Gel permeation chromatography

   c) End group analysis

3. Determination of effect of free radical intiators on molecular weight

4. Preparation of Polymers

   a) Preparation of plystyrene/PMMA through various sythesis techniques such as bulk, solution, suspension and emulsion polymerisation techniques

   b) Grafting of NR

   c) Preparation of cured epoxy resins.

   d) Preparation of cured unsaturated polyester resin.

References

1. Rabek, Experimental methods in Polymer Chemistry, John Wilely & sons (1998)
2. D. Braun, H. Cherdron, H. Ritter, Polymer Synthesis: Theory and Practice, Springer Science and Business Media (2001)
3. Stanley R. Sandler, Wolf Karo, Joanne Bonesteel, Eli M. Pearce, Polymer Synthesis and Characterization: A Laboratory Manual, Elsevier (1998)
4. K.J. Saunders , Identification of Plastics and Rubber, Chapman and Hall

24-440-0112 Polymers for packaging

Course Outcome

On successful completion of the course, the students will be able to:

CO1: Determine various physical, mechanical and barrier properties of plastic packaging films

CO2: Analyse the gas barrier properties of packaging films

CO3: Assess the capability of film and packaging materials to withstand wear, pressure and damage

1. Determination of tensile stregth and tear strength of packaging films using UTM
2. Determination of Impact resistance of films
3. Determination of puncture resistance of packaging films
4. Determination of bond strength and peel strength of poymer films
5. Determination of gas barrier properties of pckagaing films using various gases like O_2, N_2, CO_2 etc.

References

1 ASTM standards, ISO standards

Mapping of course outcomes with program outcomes: Level - Low (1), Medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	1	2	1	2
CO2	2	1	1	2	1	2
CO3	1	1	1	1	1	2

24-440-0113 Advanced Polymer Rheology

Course Outcome

On successful completion of the course, the students will be able to:

CO1: Analyse the viscosity of polymers based on the experiments

CO 2: Analyse the dynamic mechanical properties of polymers

CO 3: Understand the effect of strain rates on mechanical properties

1. Determination of melt viscosity using capillary rheometer
2. Determination of die swell
3. Determination of Brookfield viscosity.
4. Determination of MFI
5. Determination of post moulding shrinkage
6. Determination of creep
7. Determination of stress relaxation
8. Determination of storage modulus, loss modulus and loss tangent
9. Determination of effect of frequency on dynamic mechanical properties
10. Determination of strain rate on mechanical properties

References

1. ASTM, BIS, ISO standards

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**1**	**1**	**1**	**1**	**1**	**2**
CO2	**1**	**1**	**1**	**1**	**1**	**2**
CO3	**1**	**1**	**1**	**1**	**1**	**2**

24-440-0114 Characterisation and Testing Methods

Course Outcome

On successful completion of the course, the students will be able to:

CO1: Understand the modelling of various parts of polymers by using CAD

CO 2: Understand the principle and working of 3D printers

1. Determination of melt viscosity using capillary rheometer
2. Determination of die swell
3. Determination of Brookfield viscosity.
4. Determination of MFI
5. Determination of post moulding shrinkage
6. Determination of creep
7. Determination of stress relaxation
8. Determination of storage modulus, loss modulus and loss tangent
9. Determination of effect of frequency on dynamic mechanical properties
10. Determination of strain rate on mechanical properties

References

1. ASTM, BIS, ISO standards

2. CAD software tutorial

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	1	1
CO2	1	1	1	1	1	1

24-440-0121 Polymers for Packaging

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Explain fundamental properties of packaging materials. (Understand)
CO 2: Compare various bioplastics suitable for packaging. (Understand)
CO 3: Identify chemical and physical changes after packaging. (Analyse)
CO 4: Discuss packaging methods for food materials. (Understand)
CO 5: Identify specific waste management methods , safety and legislative aspect of packaging materials. (Analyse)

Unit 1. Food packaging materials– Conventional, edible and biobased, advantages and disadvantages. Edible films and coatings : polysaccharide, lipid and protein based coatings. Biodegradable packaging materials: first, second and third category.

Unit 2. Properties of packaging materials – optical, tensile, bursting strength, impact strength, tear strength, stiffness, crease or flex resistance, coefficient of friction, blocking, orientation & shrinkage and barrier properties.

Unit 3. Selection of packaging materials – deteriorative reaction in foods: enzyme reactions, chemical reactions, physical change, biological change. Shelf life of foods, factors controlling shelf life.

Unit 4. Food packaging materials – microwavable foods, flesh foods, horticultural products, dairy products, packaging of cereals, snack foods & confectionary and beverages. Aseptic packaging of foods. Sterilization of packaging materials. Active packaging: active packaging systems, sachets and pads, active packaging materials, self-heating and self-cooling packages, widgets. Intelligent packaging. Modified atmospheric packaging: principle, gases used, passive and active MA. Sealing methods. Printing processes.

Unit 5. Waste management – recycling, composting, thermal treatment, landfill. Life cycle assessment. Safety and legislative aspect of packaging: Regulatory considerations, plastics packaging, metal packaging, paper packaging and glass packaging.

References:

1. Gordon L. Robertson, Food Packaging Principles and Practices, CRC press (2012).
2. R.J. Hernandez, Susan E. M. Selke, John D. Culter, Plastics packaging, Hanser Publishers (2000).
3. Stanley Sacharow, Roger C. Griffin, Jr., Basic Guide to Plastics Packaging, Massachusetts Cahners (1973).
4. S. Athalye, Plastics in Flexibles Packaging, Multi- Tech Publishing (1992).
5. S. Athalye, Plastics in Packaging, Tata McGraw Hill Publishing Company Ltd. (1992).

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	2	2	2	2	2
CO 2	2	2	2	2	2	2
CO 3	2	2	3	2	3	2
CO 4	2	3	3	2	2	2
CO 5	1	2	1	2	2	1

Revision 15%

24-440-0122 Advanced Polymer Rheology

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Analyse the viscoelastic behaviour using various models and superposition principles. (Analyse)
CO 2: Explain the failure behaviour of polymers. (Understand)
CO 3: Interpret the flow behavior of polymer melts. (Apply)
CO 4: Describe the flow of polymer melts through different cross-sections. (Understand)
CO 5: Examine the rheological behaviour in different processing equipment. (Analyse)

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

Unit 1. Viscoelastic behaviour– Response of Ideal elastic solid, pure viscous flow, viscoelastic solids and fluids. Mechanical models: Maxwell and Voigt-Kelvin models, four parameter model, Deborah number, relaxation and retardation time, generalized Maxwell-Weichert model, generalized Voigt model, Boltzmann superposition principle. Dynamic mechanical properties: storage and loss modulus, loss tangent, effect of temperature and frequency, effect of molecular weight, branching, crosslinking, crystallinity, blending. Time-temperature superposition: WLF equation. Rubber elasticity, entropic elasticity, Thermodynamics: force-temperature relations.
Unit 2. Fracture mechanics –Yielding and cold drawing, yield criteria, temperature and strain rate dependence, crazing, fracture, ductile-brittle transition temperature, brittle fracture- Griffith's theory, linear elastic fracture mechanics- fracture toughness, elastic - plastic fracture mechanics, rubber toughening, fatigue

Unit 3. Polymer melts – Time independent fluids: Newtonian fluids, non-Newtonian fluids, pseudoplastic, Bingham, dilatants. Time dependent fluids-thixotropic and rheopectic behavior. Models: two parameter models, three-parameter models. Factors influencing flow behavior: temperature, pressure, molecular weight and distribution, chain branching, shear rate, fillers,plasticizers . Flow of Newtonian fluids through circular cross-sections, parallel plate and annulus.

Unit 4. Flow properties – Power-law fluids, Rabinowitsch correction, Entry and exit effects, Bagley correction factor-estimation, wall slip, Carreau equation. Measurement of flow properties: capillary viscometers, coaxial cylinder viscometer, cone and plate viscometer- advantages and disadvantages. Defects: Melt fracture, shark skin, frozen-in orientation, draw-down, die swell-effect-L/D ratio, shear rate, temperature, fillers, molecular weight. Extensional flow- simple extension, biaxial extension, planar extension.

Unit 5. Rheology in extruders: analysis of pressure, drag and leakage flow. Rheology in injection moulding, Rheology in blow moulding, Rheology in compression, Rheology in transfer moulding.

References

1. Robert O. Ebewele, Polymer Science and Technology, 1st Edn., CRC Press (2000).
2. N. G. McCrum, C. P. Buckley, C. B. Bucknall, Principles of Polymer Engineering, 2nd Edn., Oxford University Press (1997).
3. Robert. J. Young , Peter. A. Lovell, Introduction to Polymers, 3rd Edn., CRC Press (2011). 4 R. J. Crawford, P. J. Martin, Plastics Engineering, 4th Edn., Butterworth-Heinemann (2020).
4. R.P. Chhabra, J.F. Richardson, Non-Newtonian Flow and Applied Rheology: Engineering Applications, 2nd Edn., Butterworth-Heinemann (2008).
5. J. A. Brydson, Flow properties of polymer melts, 2nd Edn., Godwin (1981).
6. B.R. Gupta, Applied Rheology in Polymer Processing, Asian Books Private Limited (2006). 8 John M. Dealy, Kurft F. Wissbrun, Melt Rheology and its Role in Plastics Processing,
7. Springer (1999).
8. F. N. Cogswell, Polymer Melt Rheology – A guide for Industrial Practice, Woodhead Publishing (1981).
9. Lawrence E. Nielsen, Robert F. Landel, Mechanical properties of Polymers and Composites, 2nd Edn., Marcel Dekker, Inc. (1994).
10. Montgomery T. Shaw, William J. McKnight, Introduction to Polymer Viscoelasticity, 4th Edn John Wiley and Sons (2018.,

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	3	3	3	2	2
CO 2	3	3	3	3	3	2
CO 3	3	3	2	2	3	2
CO 4	2	3	2	1	2	1
CO 5	3	2	2	1	2	1

Revision – 10%

24-440-0123 Characterisation and Testing Methods

Course Outcome
On successful completion of the course, the students will be able to:
CO 1 Explain the relevance of standards and specifications. (Understand)
CO 2 Distinguish the processability parameters of thermoplastics and thermosets. (Understand)
CO 3 Discuss the mechanical and dynamic mechanical properties of plastics and elastomers. (Understand)
CO 4 Analyze the characterization and test results of polymers. (Analyse)
CO 5 Interpret the test results obtained from polymer product testing. (Analyse)

Unit 1. Introduction – Specifications and standards. Importance of standards in the quality control of polymers and polymer products. Standards organizations. Preparation of test pieces, conditioning and test atmospheres. Testing of dry rubber: Determination of dirt, volatile matter, ash, nitrogen, plasticity retention index (PRI), acetone extract. Latex testing: total solids content (TSC), dry rubber content (DRC), total alkalinity, coagulum content, sludge content, KOH number, mechanical and chemical stability, volatile fatty acid (VFA) number.

Unit 2. Tests for processability parameters of rubbers – Mooney viscosity, scorch time, cure time, cure rate index - Rubber process analyzer (RPA). Processability tests for thermoplastics: MFI, cone and plate rheometer, capillary rheometer. Processability tests for thermosets: gel time, cup flow test.

Unit 3. Properties of plastics and rubbers – Mechanical : tension, compression, flexural, tear strength, dynamic stress- strain, hardness, impact strength, resilience, abrasion resistance, creep and stress relaxation, compression set, dynamic fatigue, ageing properties. Thermal: specific heat, thermal expansion, thermal conductivity, heat deflection temperature (HDT), Vicat softening point (VST). Electrical : resistivity, dielectric strength, dielectric constant**.**

Unit 4. Characterisation of polymers, blends and composites – Differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), electron spectroscopy for chemical analysis (ESCA), scanning electron microscopy (SEM), transmission electron spectroscopy (TEM), atomic force microscopy (AFM).

Unit 5. Quality control tests – Rubber products: latex dipped goods, foam, thread, hose, belts. Plastic products: laminates, films, pipes and cables.

References
1 ISO, BIS, ASTM, BS and DIN standards.
2 R.P. Brown, Plastic test methods, 2nd Edn., Harlond, Longman Scientific (1981).
3 Vishu Shah, Handbook of Plastic Testing Technology, 3rd Edn., John Wiley & Sons (2007).
4 R.P. Brown, Physical Testing of Rubbers, 4th Edn., Chapman Hall (2006).
5 J.F. Rabek, Experimental methods in Polymer Chemistry, John Wiley & Sons (1980).
6 F. Majewska, H. Zowall, Handbook of analysis of synthetic polymers and plastics, Ellis Horwood Limited Publisher (1977).
7 H.H. Williard, L.L. Merrit, J.A. Den, F.A. Settle, Instrumental method of Analysis, CBS Publishers and distributors (1986).
8 Douglas A. Skoog, F.J. Holler, Stanley R. Crouch, Principles of Instrumental Analysis, 7th Edn., Cengage Learning (2018).

9 C.A. Harper, Handbook of Plastics Elastomers & Composites, 2nd Edn., McGraw Hill Inc. (1992).

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	2	2	2
CO2	3	3	3	2	3	2
CO3	3	3	2	2	3	2
CO4	2	3	2	1	2	1
CO5	2	2	2	1	1	1

SEMESTER II

24-440-0201 ADVANCED PLASTIC PROCESSING

Course Outcome
On successful completion of the course, the students will be able to:

CO 1 Acquire fundamental understanding on the selection of appropriate additives and techniques for plastic processing. (Understand)
CO 2 Recommend a preferred plastic production process based on requirement. (Apply)
CO 3 Analyze merits and demerits from product design perspective. (Analyze)
CO 4 Develop skill to critically evaluate design of product vs performance. (Evaluate)
CO 5 Modulate processing parameters and compounding additives towards product requirement. (Evaluate)

UNIT 1. Applied Principles of Plastics Processing: Functional characteristics of polymer melts: rheological aspects of plastic processing, evaluation of mechanism of action of additives in plastic compounds, criteria for selection of processing techniques, selection criteria vs performance. Compounding and mixing: methods of incorporation of additives., mixing equipment-batch, continuous, high-speed mixers, two roll mill, Banbury, ribbon blender, planetary mixers and extruders.

UNIT 2. Extrusion: Process cycle. Factors governing efficiency. Extruder screw design vs efficiency. Special extruders: vented, reverse flow, twin screw, intermeshing and non–intermeshing, counter rotating and co-rotating. Extrudate defects and troubleshooting: shark skin, melt fracture & bambooing. Product Manufacture: co-extruded sheets, corrugated pipes, coating, lamination, profiles. Screw design for special applications of extruders. Dies and take off equipment. Post-extrusion techniques.

UNIT 3. Injection Moulding: Reciprocating screw injection moulding machines, process variables, effects on moulding quality, factors affecting moulding. Common moulding defects: causes and remedies. Thermoset injection moulding: machine description, parts and their functions, process parameters, merits and de-merits. Reaction injection moulding (RIM): features and variables, flow diagram, merits and demerits. Injection foam moulding-types, microcellular injection foam moulding. Specialized processes: reinforced pipes, fishing net, heat shrink film, cling film, corrugated sheets and pipes Nonconventional injection moulding processes: gas-assisted, sandwich moulding, structural foam, metal filled, multicolour moulding, injection moulding of reinforced thermoplastics.

UNIT 4. Special Plastic Processing Techniques: Compression moulding: materials for compression moulding, process parameters and specifications, influence of process variables. Transfer moulding: pot and plunger types, advancements, screw transfer moulding techniques, design parameters. Advantages and disadvantages of compression and transfer moulding. Thermoforming: advancements, materials and modulations in processing. Calendaring: principle, roll configuration vs products. Defects vs trouble shooting: finishing operations, product vs material/mould designs. Rotational moulding, Rotational moulding process analysis, multilayer rotational moulding, rotational moulding of thermosets.

UNIT 5. Blow Moulding and Advanced Plastic Processing Techniques: Blow moulding: stretch, co-extrusion, miscellaneous blow moulding processes, blow moulding of irregular parts. 3D printing and Additive Manufacturing Systems: Fused Deposition Modelling, Shape Deposition Manufacturing (SDM), Ballistic Particle Manufacturing (BPM), Selective Laser Melting, Electron Beam Melting. Artificial Intelligence (AI) assisted plastic processing.

References

1. Seymour S. Schwartz, Sidney H. Goodman, Plastics Materials and Processes., Van Nostrand Reinhold Company Inc. (1982).
2. D. V. Rosato, Plastic processing data Handbook, Springer (1997).
3. Norman Lee, Plastic Blow Moulding Handbook, Rapra Technology Ltd. (2006). 4 R.J. Crawford, Plastics Engineering, Butterworth – Heinemann (1998).
4. D.H. Morton Jones, Polymer Processing, Chapman and Hall (1989).
5. Joel Fradas, Plastics Engineering Handbook, Van Nostrand Reinhold Company (1978). 7 George Matthews, Polymer Mixing Technology, Elsevier Science Ltd. (1982).
6. Chris Rouwendaal, Polymer Extrusion, 5^{th} Edn., Hanser Publishers (2013).
7. John R. Wagner, Jr. Eldridge M. Mount, Harold F. Giles, Extrusion – The definitive Processing Guide and Handbook, Elsevier. Inc. (2013).
8. Walter E. Becker, Reaction Injection moulding Van Nostrand Reinhold Company (1979). 11 I.I. Rubbin, Injection moulding theory and practice, Wiley (1973).

Mapping of course outcomes with program outcomes: Level – Low (1), medium (2) and high (3)

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**
CO 1	**2**	**3**	**3**	**3**	**2**	**2**
CO 2	**3**	**2**	**3**	**3**	**3**	**2**
CO 3	**3**	**2**	**3**	**2**	**3**	**2**
CO 4	**3**	**3**	**3**	**3**	**3**	**2**
CO 5	**3**	**3**	**3**	**2**	**3**	**2**

Revision-30%

24–440–0202 Rubber Processing and Product Manufacture

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Explain the basics of NR latex preservation, processing and dry rubber production. (Understand)

CO 2: Explain the principle and operation of compounding machineries. (Understand)

CO 3: Design rubber compounds based on end-use requirements. (Apply)

CO 4: Explain various rubber processing techniques used to manufacture rubber products. (Understand)

CO 5: Identify different unit operations for rubber product manufacturing. (Analyse)

Unit 1. Natural rubber – Preserved field latex, latex concentrates – centrifuging and creaming, ribbed smoked sheets, crepe rubber, technically specified solid block forms (crumb rubber), superior processing rubbers and other modified forms of natural rubber.

Unit 2. Vulcanisation – Curatives: Sulphur, sulphur donors, accelerators, activators, non-sulphur curatives- peroxides, metal oxides, resin, high energy radiation, microwave. Mechanism of cure, estimation of cure using rheometers and swelling studies.

Other compounding ingredients: fillers- black and non black, filler characteristics such as surface area, structure and surface activity, role of filler on properties, anti-degradants, mechanism of protection, plasticisers, special purpose additives- blowing agents, antistatic agents, conducting fillers, anti-fungal agents. Design of rubber compounds to meet specific needs.

Unit 3. Rubber Processing – Machinery used for: mixing- two roll mill, internal mixers and continuous mixers, extrusion, calendering, fabric coating and spreading process.

Unit 4. Moulding techniques – Compression moulding- types of mould, the process, the hydraulic press, types of press, transfer moulding and injection moulding and autoclave curing. Continuous curing methods: rotocure, hot air, fluidized bed, LCM, molten salt bath and high energy radiation curing.

Unit 5. Rubber products – Dry rubber products: footwear, belts, hoses and tubes, wire and cables, rubber to metal bonded articles, mechanical seals, cellular products, sports goods, tank, pipe and valve linings, shock absorbers and anti-vibration mountings. Latex products: foam, gloves, balloons, prophylactics, thread. Rubber waste disposal: recycling-size reduction methods, reclaimed rubber. Pyrolysis of waste rubber.

References

1. C. M. Blow, C. Hepburn, Rubber Technology and Manufacture, 2nd Edn., Butterworth Scientific (1982).
2. Werner Hofmann, Rubber Technology Handbook, Hanser Gardner Publications (1990).
3. P. K. Freakly, Rubber Processing and Production Organisation, Springer Science & Business Media (2012).
4. Anil K. Bhowmick, Howard L. Stephens, Handbook of Elastomers, 2nd Edn., CRC Press (2000).
5. Anil K Bhowmick, Malcolm M. Hall Henry A. Benarey (Eds.), Rubber Products
6. Manufacturing Technology, Marcel Dekker Inc. (1994).
7. Robert F. Ohm (Ed.), The Vanderbilt Rubber Handbook, 13th Edn., R. T. Vanderbilt Company, Inc. (1990).

Mapping of course outcomes with program outcomes: Level – Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	2	2	2	1	2
CO 2	3	2	2	2	3	2
CO 3	3	2	3	2	3	2
CO 4	2	2	2	2	3	2
CO 5	3	3	3	2	3	2

Revision 10%

24-440-0203 Advanced Tyre Technology

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Gain knowledge about the various types of tyres and their functions.(Understand)
CO 2: Learn the mathematics underlying the design of pneumatic tyres.(Understand)
CO 3: Comprehend and envisage the processes involved in the design and production of rubber compounds and the components of various types of tyres and tubes.(Apply)
CO 4: Understand the standard practices followed in tyre retreading, tyre & tube maintenance and service. (Understand)
CO 5: Learn the non-destructive and destructive tests done on tyres and tubes. (Understand)

Unit 1. History of design and development of tyres– Current status of global and Indian tyre industry. Pneumatic tyres – tubed and tubeless tyres, basic functions and performance comparison. Components of a tyre: geometry and basic functions. Functions of pneumatic tyres: load carrying capacity, vibration and noise reduction, tyre function as a spring, contribution to driving control and road holding. Other functions of tyres. Cornering and self-aligning torque.

Unit 2. Raw materials used for tyre manufacturing– Tyre cords - reinforcing materials- their advantages and disadvantages- compounding ingredientsconstruction of different types of cords, Modification of the tyre cords and adhesion.- . Mechanics of tyre pavement interaction. Tyre forces on dry and wet road surfaces. Tractive forces on dry surface, wet surface, snow and irregular pavements. Braking and traction of tyres.

Unit 3. Production of bead unit, tyre tread, inner liner side wall - significance of retreading process. Tyre wear–Rubber friction and sliding mechanism, various factors affecting friction and sliding. Tyre stresses and deformation, tyre noise, mechanism of noise generation, effect of tread pattern, vehicle speed, etc. on noise. Recent developments in tyre technology.

Unit 4. Manufacturing process for various tyres– Two wheeler and car tyres, truck tyres, OTR, farm tyres, aircraft tyres and solid tyres. Principles of compounding for various tyre components. Compounding for winter tyres. Tyre reinforcement materials (Textile, steel, glass, etcTyre curing methods, post cure inflation, quality control tests. Design and manufacturing techniques for tyre related products: tubes, valves, flaps, bladders. Different types, features and operation of tyre building machines, bead winding machine, wire belt processing machines, bias cutters, curing presses. Recent advance in tyre technology: Tweel , and green tyre technology, Tyre design for the electric vehicle

Unit 5. Measurement of tyre properties – Static & loaded dimension and size. Tyre construction analysis, Various tyre testing systems. Force and moment characteristics, cornering coefficient, aligning torque coefficient, load sensitivity and load transfer sensitivity. Rolling resistance, non-uniformity, dimensional variations, force variations, radial force variation, lateral force variation, conicity and ply steer. Tyre balancing.. Tyre flaws and separations (X- ray, holography, etc.). Standards (BIS) for tyres, tubes and flaps. Role of Indian Tyre Technical Advisory Committee.

References

1. L.J.K. Setright, Automobile Tyres, Chapman and Hall (1972).
2. Tom French, Tyre Technology, Taylor &Francis (1989).
3. Dr. S.N. Chakravarthy, Introduction to Tyre technology, Polym Consultants - New Delhi (2012).
4. Samuel Kelly Clark, Mechanics of Pneumatic Tires, National Highway Traffic Safety Administration, U.S. Department of Transportation (1981 - Digitized on 17 Dec 2007).
5. F.J. Kovac, Tyre Technology, Goodyear Tyre & Rubber Company (1973).
6. ITTAC Standards Manual, Indian Tyre Technical Advisory Committee, New Delhi (2018).
7. Tyre Condition Guides, Indian Tyre Technical Advisory Committee, New Delhi (2018).
8. John F. Purdy, Mathematics Underlying the Design of Pneumatic Tires, University of Michigan (1963 – Digitized on 25 Jul 2011).

Mapping of course outcomes with program outcomes: Level – Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	2	2	2	2	2
CO 2	2	2	2	2	2	2
CO 3	2	3	2	2	3	2
CO 4	2	2	2	1	2	2
CO 5	1	1	2	1	2	2

Revision – 30%

24-440-0211 Plastics and Rubber Processing Lab

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Apply theoretical knowledge in formulation design and processing of Rubber products.

CO 2: understand plastic product manufacturing by diverse plastic processing techniques

1. Formulation design, compounding and manufacture of microcellular sheet.

2. Formulation design, compounding and manufacture of sponge.

3. Testing:

   a. Determination of Mechanical properties by UTM

   b. Determination of Hardness test –Shore A Durometer

   c. Density measurements– Liquid intrusion method

   d. Microstructure analysis – Scanning electron microscopy

4. Product manufacture by injection molding.

5. Product manufacture by extrusion.

6. Product manufacture by blow molding.

7. Testing:

   a. Determination of Mechanical properties by UTM

   b. Determination of Hardness

   c. Morphology assessment

   d. Trouble shooting – Typical illustrative examples

References

1 ISO, BIS, ASTM, BS and DIN standards.

2 C. M. Blow, C. Hepburn, Rubber Technology and Manufacture, 2nd Edn., Butterworth Scientific (1982).

3 R.P. Brown, Plastic test methods, 2nd Edn., Harlond, Longman Scientific (1981).

Mapping of course outcomes with program outcomes: Level – Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	1	2
CO2	1	1	1	1	1	2

24-440-0212 Specialty Polymers Lab

Course Outcome

On completion of the course, the students will be able to:

CO1: To learn the synthesis of conducting polymers (Understand)

CO2: To learn the preparation of biomaterial substrates for medical applications. (Understand)

CO3: Analyse the prepared polymers by various characterisation techniques (Analyse)

Preparation of conducting polymers

a) Synthesis of Poly(aniline)
b) Synthesis of Poly(pyrrole)
c) Preparation of biodegradable polymer substrates for medical applications
d) Preparation of alginate microspheres for drug delivery applications
e) Preparation of porous biodegradable tissue engineering scaffolds from PLA

Characterization and Testing of Specialty Polymers

a) UV
b) FTIR
c) DC Electrical conductivity
d) Optical microscopy
e) Density measurement
f) Thermogravimetric analysis
g) vii) Biodegradation evaluation in phosphate buffer saline

References:

1. Stanley R. Sandler, Wolf Karo, Jo-Anne Bonesteel, Eli M. Pearce, Polymer synthesis and characterization: A laboratory Manuel, Elsevier Inc. (1998).

2. Rabek, Experimental methods in Polymer Chemistry, John Wilely & sons (1998)

3. D. Braun, H. Cherdron, H. Ritter, Polymer Synthesis: Theory and Practice, Springer Science and Business Media (2001)

Mapping of course outcomes with program outcomes: Level – Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	1	2
CO2	1	1	1	1	1	2
CO3	1	1	1	1	1	2

24-440-0213 Advanced Polymer Nanocomposites

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Synthesis of nanomaterials

CO 2: Understand the characterisation of nanomaterials

CO 3: Synthesis of polymer nanocomposites

CO 4: Understand the characterisation of polymer nanocomposites

1. Synthesis of nanomaterials (ZnO, TiO_2, SnO_2) by sol – gel method
2. Synthesis of nanomaterials by precipitation method (ZnO, MnO_2, CuO, SiO_2)
3. Characterization of nanomaterials (ZnO, TiO_2, SnO_2) by UV – Visible spectroscopy and FTIR
4. Characterization of nanomaterials by X- Ray Diffraction analysis (ZnO, MnO_2, CuO)
5. Synthesis of Graphene via Hummer's Method
6. Liquid phase exfoliation of MoS_2 and nanoclay
7. Characterization of Graphene, MOS_2 and naoclay by FTIR, UV, SEM and TEM
8. Nanocomposite synthesis by solution mixing
9. Nanocomposite synthesis by In-situ polymerization
10. Nanocomposite synthesis by melt mixing of polymer (two roll mill and internal mixers)
11. Nanocomposite synthesis by latex stage mixing
12. Testing of polymer nanocomposite (Tensile strength, Tear strength, Hardness, Impact strength, Thermal properties, Chemical resistance and Gas barrier properties)

13. Comparison of physical properties of polymer nanocomposites and micro composite

Mapping of course outcomes with program outcomes: Level – Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	1	2
CO2	1	1	1	1	1	2
CO3	1	1	1	1	1	1
CO4	1	1	1	1	1	1

24-440-0214 Mould and Die Design

Course Outcome

On completion of the course, the students will be able to:

CO1: Learn the use of CAD for mould design (Understand)

CO 2: Able to analyse the mould flow (Analyse)

1. Mould Design using CAD

   a) Injection Mould Design
   b) Compression Mould Design
   c) Transfer Mould Design
   d) Blow mould Design
   e) Extrusion Die Design

2. Mould Flow Analysis

References:

1. Herbert Rees, Mould Engineering, Hanser (2002)
2. Jay Shoemaker, Mould Flow Design Guide: A Resource for Plastic Engineers, Vol. 10 (2006)

Mapping of course outcomes with program outcomes: Level – Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	1	2
CO2	1	1	1	1	1	2

24-440-0215 Polymers for Electrical and Electronics Applications

Course Outcome

On successful completion of the course, the students will be able to:

CO1: Synthesize conducting polymers through various techniques.

CO2: Characterize conducting polymers

CO3: Estimate the conductivity properties of conducting polymers

1. Synthesis of conducting polymers through chemical route
   a) Synthesis of Polyailine
   b) Synthesis of Polypyrrole
   c) Synthesis of Poly (o-toluidiene)

2. Synthesis of conducting polymers through electrochemical route
   a) Synthesis of Polyailine
   b) Synthesis of Polypyrrole

3. Characterisation of conducting polymers using IR, UV, XRD, TGA,SEM and TE

4. Property evaluation of conducting polymers

   a) D.C. conductivity studies
   b) Dielectric property evaluation of conducting polymers

References

1 Rabek, Experimental methods in Polymer Chemistry, John Wilely & sons (1998)

2 D. Braun, H. Cherdron, H. Ritter, Polymer Synthesis: Theory and Practice, Springer Science and Business Media (2001)

3 Stanley R. Sandler, Wolf Karo, Joanne Bonesteel, Eli M. Pearce, Polymer Synthesis and Characterization: A Laboratory Manual, Elsevier (1998)

Mapping of course outcomes with program outcomes: Level - Low (1), Medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	1	2
CO2	1	1	1	1	1	2
CO3	1	1	1	1	1	2

24-440-0216 Materials in Space applications

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Synthesize adhesive

CO 2: Prepare composites

CO 3: Synthesize high-energy binder

1. Synthesis of epoxy resin.
2. Preparation of Epoxy/Clay Nanocomposites
3. Preparation of carbon-fibre reinforced epoxy composite by compression molding.
4. Evaluation of sress-strain properties of the composites
5. Preparation of Resorcinol-formaldehyde based carbon aerogel.
6. Synthesis of Glycidyl azide polymer

Mapping of course outcomes with program outcomes: Level - Low (1), Medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	1	1	2
CO2	1	1	1	1	1	2
CO3	1	1	1	1	1	2

24-440-0221 Specialty Polymers

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Summarize the different types of high temperature resistant polymers. (Understand)
CO 2: Outline the working principle of various devices made of conducting, photo-conducting, piezoelectric, pyroelectric polymers. (Analyse)
CO 3: Understand the rheology of liquid crystalline polymers. (Understand)
CO 4: Describe the types of ionic conducting polymers. (Understand)

CO 5: Identify the uses of polymeric materials for different medical devices. (Analyze)

Unit 1. High temperature and fire resistant polymers – fluoropolymers, aromatic polymers, hydrocarbon polymers, polyphenylene sulphide, polysulphones, polyesters, aromatic polyamides, polyketones, heterocyclic polymers, fire resistant polymers, flame retardants.

Unit 2. Polymers with electrical and electronic properties – conducting polymers, conducting mechanisms, charge carriers. Synthesis and properties of conducting polymers: polyacetylene, polyaniline, polypyrrole, polythiophene. Doping: dopants, doping techniques, applications. Photoconducting polymers. Polymers with piezoelectric, pyroelectric and ferroelectric properties. Polymers in photoresists for semiconductor fabrication: negative photoresists, positive photoresists, electron beam photoresists, plasma developable photoresists.

Unit 3. Liquid crystalline polymers (LCPs) – Concept of liquid crystalline (LC) phase, liquid crystalline polymers and their classification, main chain LCPs and side chain LCPs, structure-property relationship, applications of LCPs. Introduction to smart polymers, dendritic polymers and shape memory polymers.

Unit 4. Ionic polymers – Synthesis and physical properties: Ion-exchange, hydrophilicity, applications, ionomers based on polyethylene, elastomeric ionomers, ionomers based on polystyrene, PTFE, ionomers with polyaromatic backbones. Polyelectrolytes: ion exchangers, polyelectrolytes based on carboxylates, polymers with integral ions, polyelectrolyte complexes.

Unit 5. Polymers for biomedical applications – Biomaterials: definition and classifications. Biocompatibility: concept and validation, cell-biomaterial interactions, invitro- and invivo assessment. Biodegradation. Biocompatible polymers: silicones, polyurethanes, hydrogels. Biomedical applications of polymers: cardiovascular, dental, orthopaedic, ophthalmological, wound dressing, sutures and drug delivery.

References

1. Manas Chanda, Salil K. Roy, Industrial Polymers, Specialty Polymers, and their Applications, CRC Press (2009).

2. Faiz Mohammad (Ed.), Specialty Polymers: Materials and Applications, I.K. International Pvt. Ltd, (2008).

3. Manas Chanda, Salil K. Roy, Plastics Technology Hand book, 5th Edn., CRC press (2018).

4. Jiri George Drobny, Polymers for Electricity and Electronics - Materials, Properties and Applications, 1st Edn., John Wiley & Sons (2012).

5. Pardip Kar, Doping in Conjugated Polymers, John Wiley & Sons (2013).

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7. Buddy D., Allan S. Hoffman, Frederick J. Schoen and Jack E. Lemons (Eds.), Biomaterial Science: An Introduction To Materials In Medicine, Academic Press (2012).

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Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6

CO1	2	2	3	2	2	2
CO2	3	3	3	2	3	2
CO3	2	2	2	2	2	1
CO4	2	2	2	1	2	1
CO5	1	1	2	1	3	1

Revision: 0 %

24-440-0223 Advanced Polymer Nanocomposites

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Understand the basics of composites and carbon nanostructures. (Understand)

CO 2: Understand the structure and properties of ceramic nanomaterials. (Understand)

CO 3: Explain the synthesis and properties of polymer nanocomposites.(Apply)

CO 4: Properties of elastomeric nanocomposites and design nanoengineered polymers. (Analyze)

CO 5: Get an insight into the concepts of Nano Engineering and find the areas of pportunity in nanotechnology research. (Apply)

Unit 1. Introduction to composite materials and carbon nanostructures – Introduction to composite materials: Classification, different methods of preparation and applications. Classification based on the dimensionality:nanoparticles, nanoclustures, nanorods, nanotubes, nanowires, nanofibers and nanodots. Structure and properties of canrbon nanomaterials: CNT, fullerene, Graphene. Synthesis of graphene: Modified Hummer's method, electrochemical exfoliation and CVD method. Synthesis of CNT by CVD and arc discharge method.

Unit 2. Ceramic nanostructures and materials modifications – Introduction of ceramic nanomaterials: SiO_2, ZnO, nanoclay, hBN, MoS_2, and WS_2. Structure and classification of nanoclay : 2:1 nanocly and 1:1 nanoclay. Modification of nanomaterials like CNT, Graphene and Clay for polymer nanocomposites.

Unit 3. Sythesis of polymer nancomposite – Introduction of synthesis of polymer nanocomposite: Solution process, Latex stage mixing, Melt mixing In-situ polymerization, Polymer nanocomposite preparation by emulsion and suspension polymerization. Electrospinning and production of polymer nanocomposite nanofibers. Electrospun nanofibers for energy storage (batteries and super capacitors), membrane, defense and biomedical applications.

Unit 4. Elastomeric nanocomposites and nanoengineered polymers – Nanocomposite with elastomeric matrix : NR, SBR and TPE. Reinforcement mechanism of nanocomposite with elastomeric matrix. Preparation of bucky paper and fiber spinning of CNT and Graphene for reinforcing polymer nanocomposite. Mechanical and thermal properties of elastomeric polymer nanocomposite. Advantages and disadvantages of nanosized fillers in polymer nanocomposite, 2D polymers: Synthesis and applications.

Unit 5: Design and applications of polymer nanocomposites – Design of high performance polymer nanocomposite, Factors affecting properties of polymer nanocomposite. Thermal and Physical properties of polymer nanocomposite. Mechanism of enhanced thermal, chemical and gass barier properties of polymer nanocomposites. Applications of polymer nanocomposites: energy, environment, defense and structural applications.

Reference

1 Stelbin Peter Figerez, Prasanth Raghavan, Graphene and Carbon Nanotube for Advanced Lithium Ion Batteries, CRC Press (2018).

2 Vijay Kumar Thakur, Manju Kumari Thakur, Chemical Functionalization of Carbon nanomaterials: Chemistry and Applications, Taylor & Francis Group (2015).

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4 Suresh G Advani, Processing and Properties of Nanocomposites, World Scientific Publishing (2007).

5 Parag Diwan and Ashish Bharadwaj, Nanocomposites, Pentagon Press (2006).

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Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	2	2	2
CO2	2	2	2	2	2	2
CO3	2	3	2	2	3	1
CO4	2	3	2	1	2	1
CO5	1	2	2	2	3	1

Revision: 0 %

24-440-0224 Mould and Die Design

Course Outcome

On successful completion of the course, the students will be able to:

CO 1 Comprehend the mathematical calculations involved in the planning and design of moulds and dies. (Evaluate)

CO 2 Suggest the machinery required for the manufacture of various components of moulds and dies. (Analyse)

CO 3 Comprehend and envisage the processes involved in the design and production of various types of injection moulds. (Analyse)

CO 4 Get an insight into the design and manufacture of moulds for compression, transfer, rotational and blow moulding processes. (Understand)

CO 5 Learn the maintenance, repair and storage of moulds and dies. (Remember)

Unit 1. Mould engineering – Introduction, basic functions of the mould, types of mould. Shrinkage of plastic materials. Calculation for the number of cavities based on available machine hour. Calculation of mould clamping force. General mould design guidelines and steps. Machine specifications. Product drawing and specifications.

Unit 2. Materials for mould manufacture – Specifications, composition, heat treating, stress relieving, carburizing, nitriding, mould finishing, polishing, mould fatigue. Screws in moulds. Rules and calculations for design. Machinery for mould manufacture : cutting, turning, milling, drilling, welding, hobbing, EDM and electro-deposition.

Unit 3. Moulds for injection moulding – Construction, design of split moulds, moulds for threaded products, stack moulds, runner-less moulds. Ejection system. Feed system. Parting surfaces. Mould cooling. Venting in injection moulds. Moulds for thermosets and rubbers. Methods of fitting moulds to the injection moulding machine platens.

Unit 4. Compression moulds –Types, components of compression moulds, mould design. Transfer moulds: general types, components, design. Moulds for thermoforming. Moulds for rotational moulding and slush moulding. Design of prototype and short-term moulds. Mould maintenance, repair and storage.

Unit 5. Introduction to the rheology of polymeric materials – Simple basic equations representing flow in extrusion dies, flow through circular tube, flow in an annulus. Extrusion dies: discharge of single melt, basic types, pipe, sheet and blown film, wire coating dies, profile dies. Automatically adjustable dies. Dies for extruding nets. Dies for co-extrusion. General rules for die design. Systems for sizing and calibration of extrudates.

References

1. Gunter Mennig, Klaus Stoeckhert (Eds.),3rd Edn., Mould- Making Handbook, Hanser Publishers (2012).

2. Chris Rauwendaal, Understanding Extrusion, 2nd Edn., Hanser Publications (2010).

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Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	2	3	2

CO2	3	3	3	2	3	2
CO3	3	3	2	3	3	1
CO4	2	3	2	2	2	1
CO5	1	1	2	1	2	1

Revision: 0 %

24–440–0225 Polymers for Advanced Electrical and Electronics Applications

Course Outcome
On successful completion of the course, the students will be able to:

CO 1:	Understand the basic concepts of conducting polymers, laws of conductivity, doping process and conduction mechanism. (Understand)
CO 2:	Synthesize various classes of conducting polymers and fabricate devices based on conducting polymers (Analyse)
CO 3:	Get an insight into the processing and properties of conducting polymers.(Analyse)
CO 4:	Understand the synthesis, properties and applications of ionically conducting polymers.(Understand)
CO 5:	Analyze various applications of conducting polymers based on their properties. (Analyse)

Unit 1: Basics on inorganic and organic semiconductors–Introduction to inorganic and organic semiconductors. Classification of materials based on electrical conductivity. Basic laws on electrical conductivity: Ohm's Law, Watt's Law, Kirchhoff's Current Law (KCL), Kirchhoff's Voltage Law (KVL), Faraday's Law, Lenz's Law, Coulomb's law, Gauss's Law, Valance band theory- basic concept of band model. Molecular orbit theory-basic concept. Concept of doping and doping techniques: p-type and n-type doping and doping mechanism. Inorganic and organic dopants. Type of doping technique. Charge carriers polarons, bipolarons and solitons. Effect of doping on the properties of organic and organic semiconductors. Effect of temperature on conductivity of inorganic and organic semi-conductors. p-n junctions and characteristics of p-n junctions: depletion layer, bias current, breakdown voltage, Oxidative and reductive dopants

Unit 2: Historical development and synthesis of important conducting polymers– Introduction to electronically conducting polymers. Historical development of organic conductors. Discovery of polyacetylene. Conducting polymers and Nobel Prize. Basic structural characteristics of organic conductors. Methods of preparation of conducting polymers: Chain growth polymerization, Step growth polymerization. Polymerization techniques: Chemical polymerization, electrochemical polymerization. Template synthesis, precursor synthesis, soluble polymers (colloids and dispersions). Metathesis polymerization (Ring opening metathesis polymer (ROMP). Redox type polymers (electro active polymers). Synthesis of organic conductors: poly acetylene, poly-para phenylene, polyphenylene vinylene Synthesis of Polyhetero cyclic and polyaromatic conducting polymers: polyaniline, polypyrrole, polythiophene, polypyridine, polyvinyl carbazole. Conduction mechanism in organic conductors. Poloron, bipolron and solitons. Interchain and intra chain conduction.

Unit 3: Properties and Processing of conducting polymers– important properties of conducting polymers: electrical conductivity, photo conductivity, thermal conductivity, charge storage capacity, photoluminescence and electro luminescence. Dielectric properties of conducting polymers in high and very high frequency fields (a.c) ultra-high frequency field (microwave field) Dielectric constant, dielectric loss and absorption properties of conducting polymers in the a.c and microwave fields. Processing of conducting polymers. Methods to enhance the processability of conducting polymers. Advantages and disadvantages of conducting polymers

Unit 4. Ionically conducting polymers and their electrical applications– Ionically conducting polymers. Proton exchange membranes. Synthesis of Nafion membrane and PEEK proton exchange membranes. Sulphonation and protonation of polymeric membranes. Ionomers and poly electrolyte. Single ion conductors. Application of ionically conducting polymers for energy storage applications: rechargeable batteries, super capacitors and fuel cells.

Unit V: Analytical Techniques for Characterization and testing of conducting polymers: Impedance spectroscopy, Thermo gravimetric analysis, Scanning Electron microscopy (SEM), Transmission electron microscopy (TEM), Electrical and ionic conductivity measurement. Temperature dependant ionic transportation in polymers. Applications of conducting polymers: Rechargeable batteries, supercapacitors, optical applications, display systems, o-LED, antistatic coating, Telecommunication system, Electromagnetic screening material, aerospace applications.

Reference

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7. Pradip Kar, Doping in Conjugated Polymers Scivener Publishing , (2013).
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Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	3	3	2	2	2
CO 2	3	3	3	2	3	2
CO 3	2	3	2	2	3	1
CO 4	2	3	2	1	2	1
CO 5	1	1	2	1	2	1

Revision: 30%

24-440-0226 Materials in Space Applications

Course Outcome

On successful completion of the course, the students will be able to:

CO 1	Describe synthesis, processing and applications of high temperature polymers. (Understand)
CO 2	Explain composites for satellites and launch vehicles. (Understand)
CO 3	Describe carbon based materials, ceramic materials and metallic materials used for space applications. (Apply)
CO 4	Explain materials used in cryogenic applications. (Understand)
CO 5	Employ polymers as propallent binders. (Apply)

Unit 1. Polymers for aerospace research – Adhesives, coatings and ablatives. Synthesis, processing and applications of high temperature polymers : Aromatic liquid crystalline polyesters, phenolics, polyimide, bismaleimide, polyether etherketones.

Unit 2. Composites for satellites and launch vehicles – Composites. Type of composites : fibre composites, particulate composites and foam composites. Polymer matrix : desired properties of a matrix, thermosets and thermoplastics. Carbon based materials: carbon fiber carbon-carbon composites- production, properties and applications, carbon aero-gels, carbon foams,. Advanced fabric materials- Carbon phenolics, Silicon phenolics.

Unit 3. Polymers for thermal protection systems-Synthesis and processing of thermal protection systems in space research, high temperature resistant resins such as epoxy, phenolic . High temperature resistant polymers with metals in their back bone - Boron, Silicon and Phosphorous containing polymers for space applications. Thermofoaming Polymers-PU foaming.

Unit 4. Materials for space environment- Space radiation environment, Radiation effects, Radiation shielding materials, atomic oxygen resistant materials, space suit materials and materials for life support systems. Ultra high molecular weight polyethylene (UHMWPE): fundamentals, processing of UHMWPE- ram extrusion, Screw extrusion, Radiation shielding properties of polymers

Unit 5. Propellants – Classification of propellants: solid, liquid, hybrid and air breathing. Solid propellants : homogenous-single base and double base propellants, heterogeneous propellants, Composite propellants: preparation of oxidiser, fuel, mixing of ingradients, curing and testing of solid composite propellants. Propellant binders: high energy binders- synthesis, characteristics, pplications. Materials for cryogenic applications- cryo insulation materials, polymers and adhesive for cryo temperature applications.

References

1 S.C Lin, E.M. Pearce, High Performance Thermosets, Chemistry, Properties and Applications, Hanser Publictions (1994).

2 C.A. Dostal, Engineered Materials Handbook Adhesives and sealants, Vol.3, ASM International (1990).

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9 R.R. Luise, Applications of High Temperature Polymers, 1st Edn. CRC press (1996).

10 C. Boyars, Klager K., Propellants manufacture, Hazards and Testing, Advances in Chemistry Series, Vol.88, American Chemical society (1969).

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	2	2	2	2	2
CO 2	2	2	2	2	2	2
CO 3	3	2	3	2	3	1
CO 4	2	2	2	1	2	1
CO 5	2	2	2	1	2	1

Revision – 25%

SEMESTER III

24-440-0321 Adhesives and Surface Coatings

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Understand the basics and theories of adhesion. (Understand)

CO 2: Identify suitable adhesive formulation for various applications. (Analyse)

CO 3: Understand the mechanism of adhesion and design different adhesive joints . (Understand)

CO 4: Understand pigment properties and prepare paint dispersions (Understand)

CO 5: Evaluate the various paint properties (Analyse)

Unit 1. Introduction to Adhesives – Adhesive bonding, characteristics and functions of adhesives. Adhesive and cohesive failure. Structural and non-structural adhesives. Classification of adhesives. Theories of adhesion: Adsorption, mechanical, diffusion and weak boundary layer theories. Wettability. Surface energy. Contact angle. Work of adhesion and cohesion.

Unit 2. Classification and Composition of Adhesives – Classification based on origin, function, chemical composition, and method of reaction: single-part, multi-part, hot-melt, pressure sensitive etc. Epoxy, urethane, acrylic, phenolic, cynoacrylate, silicone, water based adhesives etc. Adhesive compositions and applications – Adhesive compounding additives: binders, hardeners, solvents, fillers, plasticizers etc.

Unit 3. Performance and application of adhesives – Types of stresses acting on adhesive joints: Tension/compression, shear, cleavage and peel stresses. Factors affecting stress distribution. Factors affecting adhesive performance. Adhesive composition. Design of adhesive joints. Testing of adhesives and adhesive joints. Adhesives for special environments- high/low temperature, thermal cycling, vacuum, UV, ozone and corrosive atmosphere. Adhesives for specific substrates.

Unit 4. Paint Basics – Significance of paint, Components of paint- Pigments, Binders, Solvents, various additives. Properties of pigments, Preparation of pigment dispersion, Factors affecting dispersion, Surface preparation and Paint application techniques. Paint preparation and formulation. Mechanism of film formation.

Unit 5. Paint Properties – Paint properties and their evaluation- wet properties: fineness of grind, viscosity, Weight Per Litre, Non-volatile matter (NVM), Medium separation, settling, drying properties, ease of application, flow and levelling, spreading rate, flashpoint; dry properties: hiding, gloss, scratch hardness, flexibility and adhesion, impact resistance, cross cut adhesion, chemical resistance, abrasion and scrub resistance, antimicrobial, corrosion and weathering resistance. General paint defect, Causes and remedies.

References

1 E. M. Petrie, Handbook of Adhesives and Sealants, 2nd Edn., McGraw Hill Handbook (2007).

2 A. Pizzi, K.L. Mittal, Handbook of Adhesive Technology, 2nd Edn., Marcel and Dekker Inc. (2003).

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4 S. Paul, Surface Coatings, 3rd Edn., Wiley (1996).

5 W.M. Morgen, Outline of Paint Technology, 3rd Edn., CBS Publishers (2000).

6 D. Stoye, Paint Coatings and Solvents, 2nd Ed.,Wiley VCH- (1998)

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	2	2	2	2	2
CO 2	3	2	2	2	3	2
CO 3	2	2	2	2	2	2
CO 4	2	3	2	1	2	1
CO 5	2	2	2	2	3	2

24-440-0322 Advanced Biomaterials for Medical Applications

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Gain fundamental knowledge on the approaches followed in the regenerative tissue e

CO 2: Obtain a comprehensive knowledge on polymeric medical devices. (Understand)

CO 3: Gain principles of advanced drug delivery.(Understand)

CO 4: Design Polymer - Bioceramics Composites for biomedical applications. (Create)

CO 5: Design of Nanomedicine for targeted drug/gene delivery for cancer therapy. (Create)

Unit 1. Biomaterials – Factors affecting the success of biomaterials in biological milieu. Biomaterial interactions: with blood, cells and tissues. Inflammatory responses associated with implantation of biomaterial. In vitro and in vivo testing protocols. Biocompatibility assays and animal models. International standards followed for biomaterials and medical devices: FDA, ISO, ASTM.

Unit 2. Tissue Engineering – Principles of tissue engineering, polymer porous scaffolds for tissue engineering applications. Fabrication of tissue engineering scaffolds techniques: self assembly, phase separation, electrospinning, 3D bioprinting and 4D printing. Hydrogels. Biomaterials for biological factor delivery: gene, growth factor and stem cell delivery. Design of a typical drug delivery system.

Unit 3. Biomimetic approaches for advanced biomaterials design – Biomineralization and biomimetics, surface modification techniques for improving biocompatibility/imparting biomimetic response. Biomimetic approaches for bone tissue regeneration. Surface functionalization of polymers for biomedical applications. Regenerative medicine.

Unit 4. Implants and medical devices – Design of medical devices. Important medical devices: heart valves, vascular grafts and extracorporeal device. Hard tissue implants: orthopaedic implants, fracture plates, spinal fixation, urinary catheters, wound dressing, cosmetic and maxillofacial implants. Soft tissue implants-contact lenses. Controlled drug delivery systems.

Unit 5. Nanomedicine – Concept, significance and attractions, targeted drug/gene delivery, factors affecting the functioning of nanomedicine. Physiological and cellular barriers of nanomedicine: significance of shape, size and functional groups associated with surface engineering of nanoparticles. Smart targeted drug delivery systems. Passive and active targeting. Magnetic nanomedicine.

References

1. Joon Park, R. S. Lakes, Biomaterials: An Introduction , 3rd Edn., Springer Science (2007).

2. Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons, Biomaterials Science: An Introduction to Materials Science, 3rd Edn., Elsevier Academic Press (2004)

3. Richard J. Miron, Yufeng Zhang, Next-Generation Biomaterials for Bone & Periodontal Regeneration., Quintessence Publishing (2019).

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5 Claudio Migliaresi, Antonella Motta, Scaffolds for Tissue Engineering: Biological Design, Materials and Fabrication, 1st Edn., CRC press (2014).

6 D. A. Puleo, Rena Bizios, Biological Interactions on Materials Surfaces - Understanding and Controlling Protein, Cell, and Tissue Responses, Springer (2009).

7 P Ducheyne, K. Healy, D. W. Hutmacher, D. W. Grainger, C. James Kirkpatrick,Comprehensive Biomaterials II, 2nd Edn., Elsevier (2017).

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9 Nihal Engin Vrana, Cell and Material Interface: Advances in Tissue Engineering, Biosensor, Implant, and Imaging Technologies (Devices, Circuits, and Systems)., 1st Edn., CRC Press (2015).

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11 Ohn Haycock, Arti Ahluwalia, J. Malcolm Wilkinson, Cellular In Vitro Testing: Methods and Protocols., 1st Edn., Jenny Stanford Publishing (2014).

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14 Bikramjit Basu, Biomaterials Science and Tissue Engineering: Principles and Methods, Ist Edn., Cambridge University Press (2017).

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	2	2	2	2	2
CO 2	2	2	2	2	2	2
CO 3	2	2	2	2	2	2
CO 4	3	3	2	2	3	2
CO 5	3	3	2	2	3	2

20-440-0323 MODELLING AND SIMULATION

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Learn discrete event simulation, reliability problem [Understand]

CO 2: Learn parameterization of continuous and discrete distributions, empirical distributions, summary statistics, estimation of parameters, fit non stationary Poisson process. [Analyse]

CO 3: Know techniques of random number generation, its properties, generation of inverse transform technique and acceptance- rejection technique and queing models.[Understand]

CO 4: Learn verification, calibration and validation and validating of input- output and analysis of simulation data.[Analysis]

CO 5: Learn simulation of manufacturing and material handling systems and features of simulation languages.[Analysis]

Unit 1. Simulation: Definition, Areas of Application, System: Discrete and Continuous Systems, Model of System, Steps in a Simulation Study. General Principles of Discrete Event–Simulation, Event Scheduling/Time Advance Algorithms, World Views, Simulation Examples: Single and two channel queues, Newspaper Selling Problem, Reliability Problem, Lead-Time Demand -Continuous System and Hybrid System Simulation Models and Applications, Monte Carlo Simulation.

Unit 2. Input Modelling: Useful Probability Distributions, Parameterization of Continuous Distributions, Continuous Distributions, Discrete Distributions, Empirical Distributions, Techniques for Assessing Sample Independence, Hypothesizing Families of Distributions: Summary Statistics andhistograms, Quantile Summaries and Box Plots, Estimation of Parameters, Goodness-of-Fit Tests, Fitting Non-Stationary Poisson Process, Selecting Input Models Without Data, Multivariate and Time Series Input Models.

Unit 3. Random Number Generation, Properties of Random Numbers, Techniques of Generation of Pseudo–Random Numbers, Test for Random Numbers, Random Variate Generation: Inverse Transform Technique, Convolution Method, Acceptance–Rejection Technique. Queuing Models, Long Run Measures of Performance, Steady State Models M/G/1, M/M/1/N/∞, M/M/C/∞/∞, M/M/C/K/K.

Unit 4. Verification, Calibration and Validation, Face Validity, Validation of Model Assumption, Validating Input-Output. Analysis of Simulation Data: Output Analysis for Terminating Simulations, Output Analysis for Steady State Simulations.

Unit 5. Simulation of Manufacturing and Material Handling Systems: Modeling of Manufacturing System, Material Handling Systems, Goals and Performance Measurement, Modeling of Down Times and Failures, Trace Driven Models; Features of Simulation Languages: Promodel– Extend - Auto Mod – Taylor II – Witness, Simul8– AIM – Arena -Basic Introduction to Agent Based Simulation and Applications.

References

1 Jerry Banks et.al. : Discrete – Event System Simulation, Fifth Edition, Prentice Hall, 2009.

2 Law A. M: Simulation Modeling and Analysis, Fifth edition, McGraw Hill New York, 2015.

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Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	1	2	2	1	2	2
CO 2	2	2	2	2	2	2
CO 3	1	1	2	1	2	2
CO 4	2	2	2	2	2	2
CO 5	2	2	2	2	2	2

20–440–0341 Dissertation - I

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Perform literature survey (Analyse)

CO 2: Analyse the recent technology developments in the field of polymer engineering.

CO 3: Perform experiments related to a research problem. (Apply)

CO 4: Design experiments related to the development of polymer products. (Create)

CO 5: Assess the experimental data generated during the experimental work.(Analyse)

Project Plan:

Do through literature survey to acquire in-depth knowledge on the research topic assigned by the company/ institution. Finalization of the objectives and methodology relating to the assigned topic, preparing a detailed work plan for conducting the project work, including team work. Design the experiments and do the research work for attaining the initial objectives of the research problem. Preparing a report in the standard format for being evaluated by the assessment board.

Evaluation

Maximum Marks : 100
(i) One internal assessment. Evaluation by the faculty supervisor/ internal faculty members
(Report and presentation)

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	3	3	3	3	2
CO 2	2	3	3	3	3	2
CO 3	2	3	3	3	3	2
CO 4	2	3	3	3	3	2
CO 5	2	3	3	3	3	2

SEMESTER IV

20-440-0441 Dissertation II

Course Outcome

On successful completion of the course, the students will be able to:

CO 1: Complete literature survey and prepare report as introduction for dissertation. (Analyse)

CO 2: Design and perform experiments related to the development of polymer products (Create)

CO 3: Analyse and solve problems related to polymer industries, Analyse results. (Analyse)

CO 4: Develope components, products, processes or technologies in the polymer engineering field. (Create)

CO 5: Interpret results and make reports based on the project work, Apply knowledge gained in solving real life engineering problems. (Analyse)

Project Plan:

Do through literature survey to aquire indepth knowledge on the research topic assigned by the company/ institution. Finalization of the objectives and methodology relating to the assigned topic, preparing a detailed work plan for conducting the project work, including team work. Detailed Analysis/ Modelling/ Simulation/ Design/ Problem Solving/ Experiment as needed. Final development of product/process, testing, results, conclusions and future directions. Preparing a paper for Conference presentation/Publication in Journals, if possible. Preparing a report in the standard format for being evaluated by the assessment board. Final project presentation and viva voce by the assessment board including external expert.

Evaluation

Maximum Marks : 200

Report: Project presentation and viva voce: Evaluation by the assessment board

Mapping of course outcomes with program outcomes: Level - Low (1), medium (2) and high (3)

CO 1	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 2	2	3	3	3	3	2
CO 3	2	3	3	3	3	2
CO 4	2	3	3	3	3	2
CO 5	2	3	3	3	3	2