



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Subject Code: ME03088031

Subject Name : Advanced Polyurethane Materials and Technology

w. e. f. Academic Year:	2024-25
Semester:	3
Category of the Course:	MOPEC

Prerequisite:	Basic knowledge of rubber technology, Polyurethane technology and their structure and properties.
Rationale:	The study of polyurethanes is crucial for understanding their diverse applications across industries such as automotive, construction, medical, and electronics. Polyurethanes offer exceptional versatility due to their wide range of physical, chemical, and mechanical properties, which are determined by the choice of raw materials, synthesis methods, and processing techniques. Overall, this course provides comprehensive knowledge and hands-on skills in the chemistry, modification, processing, and application of polyurethanes, equipping students with the expertise required to contribute to the development of next-generation materials. The integration of sustainable practices in polyurethane production and recycling aligns with global trends towards environmentally friendly and economically viable material solutions.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes
C01	Understand the basic chemistry, synthesis methods, and classification of polyurethanes, along with their structure-property relationships.
C02	Identify raw materials (polyols, isocyanates) and additives, and discuss their chemical modifications for sustainable polyurethane production.
C03	Explain various polyurethane processing techniques, including RIM, foaming, casting, extrusion, and their applications in composites and coatings.
C04	Analyse the mechanical, thermal, and dynamic properties of polyurethanes and their viscoelastic behaviour under different conditions.
C05	Evaluate testing methods for polyurethanes, including mechanical, thermal, and rheological characterization, alongside surface and environmental testing.



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Subject Code: ME03088031

Subject Name : Advanced Polyurethane Materials and Technology

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
L	T	PR		C	Theory		Tutorial / Practical	
			ESE (E)		PA / CA (M)	PA/CA (I)	ESE (V)	
03	00	00	03	70	30	00	00	100

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	Introduction to Polyurethane Chemistry: Basic chemistry of polyurethanes: Isocyanates, polyols, and their reactions, Polyurethane types: Rigid, flexible, thermoplastic, and thermoset polyurethanes, Polyurethane synthesis methods: Prepolymer process, one-shot method, and other variations, Structure-property relationships in polyurethanes, Classification: Flexible foams, rigid foams, elastomers, coatings, adhesives, sealants, and elastomeric films.	4	8
2.	Raw Materials and Chemical Modifications: Polyols and Isocyanates: Types, structure, and reactivity, Chain extenders and crosslinkers: Their role in adjusting polyurethane properties, Additives: Plasticizers, flame retardants, stabilizers, antioxidants, and catalysts, Modification of polyurethanes: Bio-based polyols, nanofillers, and hybrid systems, Sustainable polyurethane production: Use of renewable resources and bio-based materials.	4	8
3.	Processing Techniques for Polyurethanes: Reaction Injection Molding (RIM): Process parameters and applications, Polyurethane foaming techniques: Batch foaming, continuous foaming, and structural foams, Casting and extrusion processes for polyurethane elastomers, Spray foam and coatings: Technology for insulation and protective coatings, Polyurethane composites: Manufacturing and properties of fiber-reinforced polyurethanes, Processing challenges and optimization strategies.	6	12
4.	Mechanical and Thermal Properties of Polyurethanes: Mechanical properties: Tensile strength, elongation, hardness, and tear resistance, Dynamic mechanical properties: Flexural modulus, damping behavior, and temperature dependence, Thermal properties: Glass	6	12



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Subject Code: ME03088031

Subject Name : Advanced Polyurethane Materials and Technology

	transition temperature (T _g), thermal stability, and conductivity, Viscoelastic behavior and its relationship to formulation, Moisture absorption and environmental stability of polyurethanes, Failure modes: Deformation, cracking, and wear.		
5.	Characterization and Testing of Polyurethanes: Mechanical testing: Tensile, compression, and flexural tests, Thermal analysis: Differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), Rheological characterization: Viscosity and curing kinetics, Microscopic techniques: SEM, TEM for morphology and dispersion analysis, Surface analysis: FTIR, XPS, and contact angle measurements, Environmental testing: UV resistance, weathering, and aging.	5	15
6.	Polyurethane Elastomers and Coatings PU Elastomers: Structure-Property Relationship, Thermoplastic vs. Thermoset Elastomers, Applications in Tires, Seals, Footwear, and Medical Devices PU Coatings: Solvent-Based vs. Waterborne PU Coatings, UV-Curable PU Coatings, Applications in Wood, Automotive, and Industrial Coatings. High-performance coatings for industrial and automotive sectors, Electronics: Polyurethane encapsulants and adhesives for electronic devices, Energy efficiency and sustainability: Polyurethanes for insulation and energy-saving applications	5	10
7.	Polyurethane Adhesives and Sealants Chemistry and Curing Mechanism of PU Adhesives, One-Component vs. Two-Component PU Adhesives, Moisture-Curing and Hot-Melt PU Adhesives, PU Sealants for Construction, Automotive, and Aerospace Applications.	4	10
8.	Sustainable and Bio-Based Polyurethanes Renewable Polyols from Plant Oils and Biomass, Recycling and Circular Economy for PU Waste, Green Catalysts and Non-Isocyanate Polyurethanes (NIPU), Life Cycle Assessment (LCA) of PU Materials. Environmental impact of polyurethane production and disposal, Recycling methods: Mechanical recycling, chemical recycling, and energy recovery, Challenges and solutions in polyurethane recycling, Bio-based and sustainable polyurethanes: Development of green materials from renewable sources, Lifecycle analysis of polyurethane products, Future trends in sustainable polyurethane materials and their applications.	6	15
9.	Advanced Polyurethane Applications and Future Trends	5	10



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Subject Code: ME03088031

Subject Name : Advanced Polyurethane Materials and Technology

Smart PU Materials: Shape Memory, Self-Healing, and Conductive PU, PU Composites and Hybrid Materials, High-Performance PU for Aerospace and Defense, Nanotechnology in Polyurethane Systems, Automotive applications: Seating, insulation, bumpers, and soundproofing, Construction applications: Insulation materials, sealants, adhesives, and coatings, Medical applications: Biocompatible polyurethanes for wound dressings, prosthetics, and catheters, Future of Polyurethanes: Innovations and Market Trends.		
Total	45	100

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	10	20	10	10	10

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

References/Suggested Learning Resources:

(a) Books:

Recommended Textbooks:

1. "Polyurethanes: Science, Technology, and Applications" by W. R. K. Farthing and L. S. McElroy
2. "Polyurethanes: Chemistry, Technology, and Applications" by M. L. Smith
3. "Polyurethane Technology: Chemical, Raw Materials and Applications" by W. G. M. van Dijk
4. "Polyurethane Polymers: Design and Reactivity" by X. L. Zhao and A. H. Patterson
5. "Sustainable Polyurethanes: Development, Applications, and Life Cycle Assessment" by D. J. M. van Mele

(b List of Open Source Software/learning website:

- <https://www.openfoam.com/>
- <https://pymol.org/2/>
- <https://lammmps.sandia.gov/>



GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering

Level: PG

Subject Code: ME03088031

Subject Name : Advanced Polyurethane Materials and Technology

• <https://oli.cmu.edu/>

Suggested Course Practical List: If any

1. Synthesis and Characterization of Polyurethane Foams
2. Comparative Study of Thermoplastic and Thermoset Polyurethanes
3. Impact of Chain Extenders and Crosslinkers on Polyurethane Properties
4. Development of Bio-based Polyurethane from Renewable Resources
5. Optimization of Reaction Injection Molding (RIM) for Polyurethane Parts
6. Development of Structural Polyurethane Foams for Lightweight Applications
7. Effect of Temperature on Dynamic Mechanical Properties of Polyurethanes
8. Moisture Absorption and Its Impact on Polyurethane Performance
9. Characterization of Polyurethane Elastomers Using SEM and TGA
10. UV Resistance Testing for Polyurethane Coatings
11. Comparison of Waterborne and Solvent-Based Polyurethane Coatings
12. Development of High-Performance Polyurethane Elastomers for Medical Devices
13. Life Cycle Assessment (LCA) of Polyurethane Production from Renewable Sources
14. Development of Shape-Memory Polyurethane Materials
15. Nanotechnology in Polyurethane Coatings for Enhanced Durability
16. Evaluation of Hot-Melt Polyurethane Sealants for Aerospace Applications

* * * * *