GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Engineering

Level: Under Graduate

Branch: Rubber Technology

Subject Code : BE04026021

Subject Name : Rubber Physics & its thermodynamics

w. e. f. Academic Year:	2024-25
Semester:	4
Category of the Course:	PCC-05

Prerequisite:	None
Rationale:	This subject provides a comprehensive foundation in rubber technology by integrating principles of polymer science, physics, and thermodynamics. Understanding the structure-property relationships in rubbers, classification of polymers, and polymerization techniques is essential for developing and processing rubber materials. Concepts from rubber physics, including elasticity, viscosity, and friction, help in analyzing mechanical behavior, while electromagnetic and optical properties are relevant for surface and color applications. Thermodynamic principles—such as heat of polymerization, entropy, and free energy—are critical for evaluating the energy changes during rubber processing and blending. Topics like polymer solutions, binary systems, and three-component systems further deepen understanding of compatibility and phase behavior, which are vital for advanced material design and performance optimization in the rubber industry.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes
01	Analyze the molecular structure of rubber and correlate it with its macroscopic mechanical properties
02	Explain the fundamental principles of rubber's physical behavior, including elasticity, viscoelasticity, and stress-strain characteristics
03	Apply thermodynamic principles to interpret the effects of temperature, pressure, and energy on the physical behavior of rubber.
04	Evaluate thermodynamic parameters such as entropy, enthalpy, and free energy, and relate them to molecular structure and mechanical performance
05	Predict the outcomes of polymer–solvent interactions using solubility principles to assess their impact on material performance.

Teaching and Examination Scheme:

Teaching / Learning Scheme (in Hours per semester)					Total Credits = TH/30	Assessment Pattern and Marks					Total Marks
						Theory		Tutorial / Practical			
L	T	P	PBL*	TH		ESE (E)	PA (M)	PA/ (I)	TW/ SL (I)	ESE (V)	
45	15	00	60	120	04	70	30	20	30	50	200

- ***Problem Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.***

Where L = Lecture, T= Tutorial, P= Practical, TW/SL = Term-Work / Self-Learning, TH = Total Hours, PA = Progressive Assessment, ESE = End-Semester Examination

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	Rubber Science: Introduction of science of large molecule, Classification of polymers, Forms of polymers, Tactility, Functionality, types of polymers, Degree of Polymerization, Types of polymerization Techniques, Strengthening of polymers. Structure/Property Relations in Rubbers, Conditions for Rubber like Elasticity in Polymers, Molecular Motion in Rubbers, Characteristic Properties of Rubbers, Classification of Rubbers, Chain Structure & Chemical Reactivity of Rubbers, Molecular Masses & Sizes, Determination of Reactive Molecular Mass, End group analysis, Viscosity method, General rules for Polymer Solubility, Basic Concepts & Behaviors of Elasticity, Elasticity of a single molecule, Elasticity of a Three-Dimensional Network of Polymer Molecules	06	10
2.	Rubber Physics: Density, Archimedes Principle, Laws of Flotation, Elastic Behavior of Bodies, Young's Modulus, Shear Modulus, Bulk Modulus, The four Elastic Constants, Elastic Strain Energy, Difference between Rubbery & Elastic Deformations, The Theory of Rubber Elasticity, Elastic collisions, Viscous Flow of Liquids, Measurement of Viscosity, Surface Tension, Surface Tension Measurement, Friction, Static, Sliding & Rolling Friction,	06	10

	Sliding Friction of Rubber, Rolling of Rigid bodies down Rubber tracks.		
3.	Energy & The Electromagnetic Spectrum: Electromagnetic Radiation & its Properties, Absorption & Scattering of Light, Critical Angle & Total Internal Reflection, The Refractive Index of Polymers.	05	10
4.	Basic Concepts of Thermodynamics: Terminology of thermodynamics, zero law of thermodynamics, first law of thermodynamics, second law of thermodynamics, Concept of enthalpy, reversible isotherm, heat capacity, Concept of entropy, entropy change in reversible & irreversible process, entropy of phase transition, free energy & its change of an ideal gas in isothermal change, Gibbs-Helmholtz equation.	06	10
5.	Fundamental Principles of Thermodynamics: Balance Equations, Basic thermodynamics for Rubber Elasticity & Strain induced Crystallization.	03	10
6.	Heat of Polymerization and Ceiling Temperature: Heat of Polymerization (ΔHP), Factors affecting ΔHP. Variations in Heat of Polymerization. Estimation of Heat of Polymerization. Concept of Ceiling Temperature, Spontaneity, Conditions for Polymerization Reaction.	04	10
7.	Thermodynamics of Polymer Solutions: Basic concepts of solutions, Flory-Huggins theory: Entropy of mixing on formation of a Thermal solution, change in Gibbs Free Energy on Dissolution of Polymers, Phase equilibrium in polymer solutions	04	10
8.	Thermodynamics of Binary Polymer-Polymer Systems: - Enthalpy of Mixing of Two Polymers, Free Energy of Mixing of Polymers, Entropy of Mixing of Two Polymers, Phase Diagrams of Polymer-Polymer Systems.	04	10
9.	Thermodynamic Properties: Relationship between molecular weight and two fundamental thermodynamic properties (1) Thermal conductivity (2) Coefficient of Thermal Expansion., Thermodynamic forces favoring maximum potential Crystallinity.	04	10
10.	Thermodynamics Investigation of Polymer-Polymer Systems. Three-component Systems.	03	10
	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:

1. Science & Technology of Rubber, by James E. Mark, Burak Erman, Frederich R.Eiric
2. Principles of Polymer Systems, by Ferdinad Rodrigeuz
3. Rubber Engineering, IRI
4. Physical Chemistry of Polymers, by A. TAGER, MIR Publishers-Moscow
5. Engineering Chemistry by Jain & Jain
6. Polymer Processing Principles and Design, by Donald G. Baird, Dimitris I. Collias
7. Polymer Structure, Properties and Applications by Rudolph d. Denim
8. Thermodynamics of Polymerization', Hideo Sawada.

(b) Open-source software and website:

- www.sciencedirect.com/science/book/9780124647862
- onlinelibrary.wiley.com/doi/10.1002/polb.21010/pdf
- www.sciencedirect.com/science/article/pii/0032395069902718
- www.iupac.org/publications/pac/26/3/0423/pdf/
- www.journals.elsevier.com/...journal...heat...mass-transfer/recent-articles/
- wolf.chemie.uni-mainz.de/.../thermodynamics_of_polymer_solutions.pdf
- fluid.wme.pwr.wroc.pl/.../combustion.../LIQUID_FUEL_COMBUSTION.
- www.chem.ufl.edu/~itl/4411L_f96/rubber/rubber_sav.html
- www.boundless.com › ... › The Laws of Thermodynamics

Suggested Course Practical List: If any

Practical based on above topics.

List of Laboratory/Learning Resources Required:

Suggested Project List:

1. Study of Polymer Structures and Their Influence on Rubber Elasticity.
2. Investigation of Elastic and Frictional Behavior of Rubber Materials.

3. Effect of Pigments and Fillers on Light Absorption and Scattering in Rubber.
4. Measurement of Enthalpy and Entropy Changes in Heating of Rubbers.
5. Thermodynamic Study of Strain-Induced Crystallization in Natural Rubber.
6. Experimental Estimation of Heat of Polymerization and Determination of Ceiling Temperature,
7. Compatibility Study of Rubber-Solvent Systems Using Flory-Huggins Theory,
8. Phase Diagram Construction for Rubber-Polymer Blends.
9. Effect of Molecular Weight on Thermal Conductivity and Expansion in Rubber.
10. Study of Thermodynamic Stability in Ternary Rubber Blends.

Suggested Activities for Students: If any

List of suggested activities for Problem Based Learning:

Sr. No.	Name of the activity	No. of hours	Evaluation Criteria
1.	Online Course	Minimum duration of the course should be 20 h.	Based on assignment submitted and certificate produced.
2.	Self-Learning Through Assignment Creation related to subject	Completion of five independent tasks, each designed for a 3-hour engagement. Total = 15h	Based on assignment submitted.
3.	Case Study Analysis related to subject	Duration of data collection -6 h Report preparation – 4h Total- 10 h	Based on Problem identification, depth of analysis, technical insight, application relevance
4.	Technical Article/Video Reviews related to subject	Duration of Review -6h Report preparation -4h Total-10h	Relevance of content, clarity of summary, insights drawn, conceptual understanding
5.	Literature review and Concept Mapping	Duration -6h Report preparation- 4h Total-10 h	Based on selection of a topic, creation of concept map, Accuracy, structure, completeness, clarity and coverage of key concepts

6.	Industry Interaction (Webinar/Interview/Quiz)	Total-10 h	Based on certificate produced for participation in webinar, interview, quiz and based on report submitted. Report should contain key takeaways.
7.	Peer Teaching Video	2 video preparation -10 h	Create a 5–10-minute video explaining a rubber technology concept for peers, incorporating visuals.
8.	Glossary Compilation	Duration -5h	Based on report submitted. Report should contain Accuracy, completeness, formatting, and use of illustrations/examples
9.	Videos focusing on industrial safety topics relevant to the subject	Duration of video = 5h Report preparation = 5h Total = 10h	Based report submitted. Report should contain all safety aspects explaining its importance.
10.	Peer Interaction / Teaching	5 research paper/ Technical Topics = 20 h	Communication skill, clarity of explanation, concept understanding
11.	Visual presentation of technical content through posters, charts, or PowerPoint slides	Duration = 10 h	Based on quality of poster/chart preparation, creativity, accuracy and effectiveness of presentation skills.
12.	Model-making (working or non-working) focused on technical concepts	Duration -15 h	Based on evaluation from inter-department or external experts.