w. e. f. Academic Year:	2024-25
Semester:	2
Category of the Course:	Professional Elective Course

Prerequisite:	Basic knowledge of rubber technology, rheology, compounding, and recycling technology of rubbers.
Rationale:	The inclusion of sustainability in rubber technology addresses a pressing need to align industrial practices with global environmental and socio-economic objectives. Rubber, being an indispensable material across industries, contributes significantly to ecological degradation due to conventional extraction, production, and disposal methods. The rationale for the outlined topics lies in the urgency to transition to greener, more sustainable practices, ensuring minimal environmental impact while maintaining functionality and performance. This rationale underscores the necessity of addressing environmental, economic, and social dimensions in rubber technology. By covering a comprehensive range of topics, the curriculum aims to equip professionals and researchers with the knowledge and tools required to innovate and implement sustainable practices, ensuring the long-term viability of the rubber industry while safeguarding planetary health.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes
C01	Understand and analyze the principles of sustainability and its relevance to the rubber industry.
C02	Apply and evaluate bio-based rubber alternatives and sustainable processing techniques.
C03	Design and evaluate eco-friendly rubber compounds using alternative fillers and renewable additives.
C04	Analyze recycling methods and create solutions for upcycling rubber waste with life cycle analysis.
C05	Evaluate and create advanced sustainable rubber materials for applications in green tires and biodegradable products.

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA / CA (M)	PA/CA (I)	ESE (V)	
03	00	02	04	70	30	20	30	150

Course Content:

Unit No.	Content	No. of Hours	% of Weightage
1.	**Introduction to Sustainability in Rubber Technology:** Principles of sustainability and its relevance to the rubber industry, Environmental and socio-economic challenges in conventional rubber production, Circular economy in the rubber industry.	5	10
2.	**Natural Rubber and Bio-Based Rubber Alternatives:** Sources of natural rubber: Hevea brasiliensis, guayule, and Russian dandelion, Sustainable harvesting and processing techniques, Biopolymers and bio-based synthetic rubbers (e.g., bio-isoprene, bio-butadiene).	5	10
3.	**Eco-Friendly Rubber Compounds:** Alternative fillers: biochar, nanocellulose, and natural fibers, Use of green curatives, accelerators, and non-toxic additives, Renewable plasticizers and softeners.	5	10
4.	**Recycling and Reprocessing Technologies:** Mechanical recycling: grinding, re-compounding, Devulcanization methods: thermal, chemical, and biological, Upcycling and reusability in industrial applications, Life cycle analysis (LCA) of recycled rubber.	5	10
5.	**Advanced Materials in Sustainable Rubber:** Thermoplastic elastomers (TPEs) and thermoplastic vulcanizates (TPVs), Rubber nanocomposites: sustainable production and applications, Hybrid bio-based and synthetic rubbers.	5	15
6.	**Environmental Aspects of Rubber Production:** Impact of rubber plantations on biodiversity and soil health, Carbon footprint of synthetic vs. natural rubber, Regulations, certifications, and eco-labeling for sustainable rubber.	5	15
7.	**Sustainable Additives for Rubber:** Renewable oils and resins, Green crosslinking agents: sulfur-free vulcanization methods, Stabilizers and antioxidants derived from natural sources.	5	10

8.	**Applications of Sustainable Rubber Materials:** Green tires and automotive components, Industrial products: seals, gaskets, and conveyor belts, Biodegradable rubbers for medical and consumer goods.	5	10
9.	**Future Trends and Innovations in Sustainable Rubber:** Developments in bio-based monomers and polymers, Role of artificial intelligence in sustainable material design, Potential of enzymatic and microbial rubber recycling, Analysis of industry practices in sustainable rubber manufacturing, Research on novel sustainable materials and technologies.	5	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. Natural Rubber: Biosynthesis, Culture, Processing, and Applications by M.R. Sethuraj and N.M. Mathew
2. Sustainable Composites for Lightweight Applications by Hom Dhakal
3. Handbook of Sustainable Polymers: Structure and Chemistry by Vijay Kumar Thakur and Manju Kumari Thakur
4. Green Biocomposites: Design and Applications by Mohammad Jawaid and Mohamed Thari
5. Recycling of Rubber" by Martin J. Forrest
6. The Science and Technology of Rubber" by James E. Mark, Burak Erman, and Mike Roland

(b List of Open Source Software/learning website:

- **https://www.epa.gov/sustainability**
- **https://www.ellenmacarthurfoundation.org/resources**
- **http://www.biopolymerdatabase.com/**
- **https://www.epa.gov/recycle**

Suggested Course Practical List: If any
Practical based on above topics.

Suggested Project List:

1. A Life Cycle Assessment (LCA) of Conventional vs. Sustainable Rubber Production Methods
2. Exploring the Viability of Guayule as a Sustainable Rubber Source

3. Biopolymer Synthesis and Application in Rubber Technology
4. Development of Eco-Friendly Rubber Compounds Using Biochar and Natural Fibers
5. Formulation of Green Rubber Compounds Using Renewable Plasticizers
6. Assessment of the Environmental Impact of Rubber Plantations on Biodiversity
7. Carbon Footprint Analysis of Synthetic vs. Natural Rubber Production
8. Development of Sulfur-Free Vulcanization Methods Using Green Crosslinking Agents
9. Natural Antioxidants in Rubber Compounds: Performance and Sustainability
10. Artificial Intelligence in Sustainable Rubber Material Design
11. Potential of Microbial Rubber Recycling in Industrial Applications

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