# GUJARAT TECHNOLOGICAL UNIVERSITY

**Program Name: Engineering**
**Level: Under Graduate**
**Branch: Rubber Technology**
**Subject Code : BE05026081**
**Subject Name : Vulcanization**

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| w. e. f. Academic Year: | 2024-25 |
| Semester: | 5 |
| Category of the Course: | Professional Core Course |

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| **Prerequisite:** | None |
| **Rationale:** | Vulcanization is the key process that converts raw rubber into a strong, elastic, and durable engineering material. This course provides essential knowledge of sulphur and non-sulphur curing systems, reaction mechanisms, crosslink chemistry, modern vulcanization techniques, and methods for assessing state of cure.<br>It enables students to understand structure–property relationships of vulcanizates, select appropriate curing systems, optimize processing conditions, and predict performance characteristics. The course strengthens practical competence in rubber compounding, processing, and industrial problem solving. |

**Course Outcome:**

After Completion of the Course, Student will able to:

| No | Course Outcomes | Marks % weightage |
|---|---|---|
| C01 | Explain the importance of vulcanization in Rubber | 15 |
| C02 | Differentiate vulcanizing system for olefin & non olefin rubbers | 25 |
| C03 | Relate structure and properties of Vulcanizate | 15 |
| C04 | Classify different vulcanization systems and techniques | 20 |
| C05 | Analyze of state of vulcanization | 25 |

**Teaching and Examination Scheme:**

| Teaching/Learning Scheme in hrs/semester | | | | | Total Credits | Assessment Pattern and Marks | | | | | Total Marks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Theory | | Practical | | | |
| L | T | P | PBL* | TH | TH/30 | ESE (E) | PA (M) | PA (I) | PBL(I) | ESE (V) | |
| 45 | 0 | 30 | 15 | 90 | 3 | 70 | 30 | 20 | 30 | 50 | 200 |

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

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

**Course Content:**

| Unit No. | Content | No. of Hours | % of Weightage |
|---|---|---|---|
| 1. | Introduction:<br>Drawbacks of Raw Rubber, Definition of Vulcanization, Properties of Unvulcanized Compound, Difference between Vulcanized Rubber and Unvulcanized Rubber, Structural Changes observed in Rubber After Vulcanization, Structure of Rubber Vulcanizate. | 05 | 10 |
| 2. | Sulphur Vulcanization :-<br>Practical systems for Natural & Synthetic Olefin Rubber-Theory of Sulphur vulcanization. | 04 | 10 |
| 3. | Non-sulphur vulcanizing systems for olefin & Non-olefin Rubbers: Metallic oxides, Polyfunctional amines, peroxides for polyacrylates, Silicone Rubbers, Fluorocarbon Rubbers. | 04 | 10 |
| 4. | Types of Vulcanizing agents & their effects:<br>1. Sulphur 2. Sulphur donors 3. Accelerated sulphur vulcanization 4. Peroxides : Introduction, Classification of Peroxides and their Structures, Examples of Peroxides, Efficiency of Peroxides, Chemistry of peroxide cure, Compounding Aspects of peroxide Cure, Advantages of Peroxides cure over sulphur vulcanization, Disadvantages, Reaction mechanism, Peroxide cure of saturated and unsaturated elastomers 5. Metal oxides: Introduction, Reaction mechanism, Suitable examples 6. Phenolic curatives: Introduction, Reaction mechanism, Suitable examples, Vulcanisation by benzoquinone derivatives, bismaliemides, Vulcanization by triazine accelerators, Urethane cross -linking. | 06 | 15 |
| 5. | Relations between Structure and Properties of Vulcanizates: Modulus and Strength, Hardness, Resilience and Heat Buildup, Fatigue Properties, Heat Stability, Swelling, Low Temperature Properties, Abrasion, Compression Set, Aging, Dynamic Properties and Rolling Friction. Evaluation of mechanical and physical properties of vulcanizates as per relevant BIS standards (IS 3400 series). | 05 | 15 |
| 6. | Different Vulcanisation System:<br>Conventional, EV and Semi EV system in rubber, Accelerator system selection & adjustment, Vulcanization of rubber blends and filled systems. | 05 | 10 |
| 7. | Modern Vulcanisation System:<br>Moisture curing, Dynamic Vulcanisation, Shrinkage and Post Vulcanisation reaction | 04 | 10 |
| 8. | Vulcanisation techniques:<br>Introduction, Classification of Vulcanization Techniques. Batch | 06 | 10 |

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| | Vulcanization Techniques: Moulding, Autoclave, Hot Air Oven Curing, Lead Curing, Moisture Curing, Free Heating: General Comments About Free heating, Difference between hot air and steam vulcanization, Vulcanization Phases During Free Heating, Comparison of Saturated Steam Vulcanization and Super heated Steam, Vulcanization in Air/Steam Mixture, Vulcanization in Water, Cold Vulcanization. Continuous vulcanization : Liquid Curing Method, Fluidized Bed Vulcanization, Continuous Vulcanization in Stem Pipes, Rotocure, Hot Air Tunnel, Comparison of Performance of CV lines. Microwave curing process and equipment, Ultrasonic vulcanization, Electron beam vulcanization, emerging methods of rubber vulcanization. | | |
| 9. | The assessment of state of vulcanization:<br>Theoretical study of degree of cross linking. -Practical assessment of state of cure. Determination of state of cure: Methods and techniques: 1. Chemical method, 2. Physical test method, 3. Continuous method, Discussion of methods of measuring cure, Calculation of cure in thick articles, The relation between curing system type & properties (Sulphur - poly olefins Rubbers), Vulcanization process by rheometer curve, Prediction of State of Cure, Cure Simulation Instruments, Prediction of State of Cure by Arrhenius equation. | 06 | 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** |
| 15 | 15 | 10 | 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. Rubber Technology & Manufacture by Blow & Hepburn.
2. Rubber Processing & Production Organization by Philip K. Freakley
3. Rubber Product Manufacture Technology by Anil K. Bhowmick

**(b) List of Open Source Software/learning website:**

- **http://digital.csic.es/bitstream**
- **https://www.tut.fi/ms/muo/tyreschool/**
- **http://dyuthi.cusat.ac.in/**
- **http://www.ajer.org/papers/rase-2-2013/Volume-3/BV120130813.pdf**

**Suggested Course Practical List: If any**

Practical based on above topics.

**Overall SDG Mapping:**

The Vulcanization course primarily supports **SDG 9** through advanced curing technologies and industrial process optimization. It contributes to **SDG 12** by promoting efficient material usage, controlled curing systems, and enhanced durability of rubber products. The course also supports **SDG 13** and **SDG 7** through energy-efficient vulcanization methods and optimized curing cycles, while ensuring safe chemical practices aligned with **SDG 3**.

**Activities suggested under 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. | Virtual /Industry Trip | Duration of hours-5h<br>Report preparation- 5h<br>Total -10 h | Based on report submitted. Report should contain manufacturing process, flow chart. |
| 3. | Assignments | Completion of five independent tasks, each designed for a 3-hour engagement.<br>Total = 15h | Based on assignment submitted. |
| 4. | Case Study Analysis related to subject | Duration of data collection -6 h<br>Report preparation – 4h<br>Total- 10 h | Based on Problem identification, depth of analysis, technical insight, application relevance |
| 5. | Technical Article/Video Reviews related to subject | Duration of Review -6h<br>Report preparation -4h<br><br>Total-10h | Relevance of content, clarity of summary, insights drawn, conceptual understanding |
| 6. | DIY Experiments | 5 hours including report preparation | Based on report submitted. Report should contain experiments performed which have Creativity, relevance to rubber properties, observation documentation, safety awareness. |
| 7. | Course Seminar | Duration -10h | Based on technical Content & Understanding, Analysis, literature review, Quality of report and presentation. |

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| 8. | Mini/ Micro Project | Duration -10h | Based on Technical Analysis, literature review, methodology, innovation/sustainability aspect, Quality of report and presentation. |
| 9. | Complex Problem solving | Duration -5h | Evaluation is based on problem complexity & clarity, analytical approach, design/experimental methodology, use of modern tools, sustainability considerations, innovation, result validation, and feasibility of solution. |
| 10. | Videos focusing on industrial safety topics relevant to the subject | Duration of video = 5h<br>Report preparation = 5h<br>Total = 10h | Based report submitted. Report should contain all safety aspects explaining its importance. |
| 11. | Visual presentation of technical content through posters, charts, or PowerPoint slides | Duration = 10 h | Based on<br>quality of poster/chart preparation, creativity, accuracy and effectiveness of presentation skills. |

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