GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering

Level: UG

Branch: Chemical Engineering

Subject Code: BE05005071

Subject Name: Green Technology and Sustainable Development

w.e.f. Academic Year:	2024-25
Semester:	5
Category of the Course:	Professional Elective Course - 2

Prerequisite:	None
Rationale:	This course introduces Green Technology as a transformative approach to the design, manufacture, and application of chemical products, emphasizing the intentional elimination of hazards at the source rather than managing them after the fact. As a rapidly evolving discipline, it focuses on the creation of safer chemicals through efficient, non-toxic synthetic pathways that safeguard both human health and the global ecosystem. By integrating these technical principles with the broader pillars of Sustainable Development, students will critically analyze the consequences of societal resource consumption and develop strategic frameworks to drive industrial practices toward a more sustainable, circular future.

Course Outcome:

After completion of the course, student will able to:

No	Course Outcomes
01	To understand the principles of green chemistry and engineering.
02	To understand the field of Green Technology and its approach towards the new discovery and innovation.
03	To gain knowledge on Green industrial processes.
04	To understand the concept of sustainable development and its importance.
05	Ability to describe Cleaner Production measures applicable to different industries.
06	Understand and select the different principles of green chemistry and sustainable development for various applications.

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.	**Principles of Green Technology and Green Engineering:** Introduction to Green Chemistry, its definition, objectives, and significance in modern chemical industries, Principles of Green Chemistry, Green Chemistry vs Green Engineering, Concept of Process Intensification: definition, objectives, and importance in modern process industries.	**07**	**15**
2.	**Green Synthesis and Catalysis:** Green synthesis in sustainable chemical processes: green oxidation and photochemical reactions with suitable examples. Microwave and ultrasound-assisted synthesis: principles and industrial significance. Green reagents and eco-friendly alternatives to hazardous chemicals, Green solvents including water, supercritical fluids, bio-based solvents, solvent-free systems, and ionic liquids. Green nanotechnology and nanocatalysts for enhanced efficiency and waste minimization in chemical manufacturing.	**07**	**20**
3.	**Green Industrial Processes:** Pollution statistics and environmental impact of polymer, textile, pharmaceutical, dye, pesticide, and wastewater treatment industries. Sources and types of industrial pollutants and their environmental implications. Green approaches including cleaner production, waste minimization, eco-friendly raw materials, energy-efficient technologies, recycling, and sustainable wastewater treatment for environmentally responsible manufacturing.	**07**	**15**
4.	**Sustainable Development (SD):** Concept of Sustainable Development, Dimensions of Sustainability: the ecological, the economic and the social dimension,intragenerational and intergenerational equity, Circular Economy, Sustainable Development Goals, Challenges in Attaining SDGs and Sustainable Development, Measures for Overcoming Challenges in Sustainable Development, Strategy for Sustainable Development.	**07**	**15**
5.	**Cleaner Production (CP):** Concept of Cleaner Production, Role of CP in Achieving Sustainability, CP Tools, CP Methodology, Environmental Management Hierarchy, Relation of CP and EMS. Case Studies: Reuse of Water & Sludge in the Process,Modernization and Up gradation of Effluent Treatment Plant, Ammonical nitrogen recovery from wastewater, Fluoride removal from wastewater, Nitrogen-based Gas Quenching (Oil Replacement),Manufacturing of Magnesium Carbonate via Novel approach.	**10**	**20**

6.	**Challenges and Practical Implementation:** Responsibilities and potentials of companies for action. Green Productivity and Emerging Technologies. Implementation of the practical applications of Green Emerging Technologies and Sustainable Development. Case studies in Green Technology. Green laws and compliance.	**07**	**15**
	Total	**45**	**100**

Overall Course SDG Mapping:

This course aligns with SDG 6: Clean Water and Sanitation, SDG 7: Affordable and Clean Energy, SDG 9: Industry, Innovation and Infrastructure, SDG 12: Responsible Consumption and Production, and SDG 13: Climate Action, by promoting green chemistry principles, cleaner production, sustainable industrial practices, and environmentally responsible technological development.

Suggested Specification Table with Marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
30	**15**	**15**	**5**	**5**	**---**

WhereR:Remember;U:Understanding;A:Application,N:AnalyzeandE:EvaluateC:Create(asper Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

References/Suggested Learning Resources:

(a) Books:

1. Chemistry for Environmental Engineering and Science, Sawyer C.N, McCarty P.L and Parkin G.F. 5th ed. McGraw-Hill Professional, 2003.
2. Environmental Chemistry with Green Chemistry, Das A. K. Books and Allied (P) Ltd., Kolkata, India, 2012.
3. Green Chemistry: Environmentally Benign Reactions, Ahluwalia, V.K. Ane Books India, New Delhi, India, 2006.
4. Green Chemistry: An Introductory Text, Lancaster M. Royal Society of Chemistry, Cambridge, 2002.
5. Introduction to Green Chemistry, Matlack A.S. Publisher: Marcel Dekker, Newyork, 2001.
6. Green Chemistry: Theory and Practice, Anastas P.T. and Warner J.C. Oxford University Press, 1998.
7. Pollution Prevention: Fundamentals and Practice, Bishop P. L. McGraw-Hill, Boston, 2000.
8. Cleaner Production Audit Environmental System Reviews, Modak P., Visvanathan C. and Parasnis M. Asian Institute of Technology, Bangkok, 1995.
9. Handbook of Green Chemistry and Technology, Clark J.H. and Macquarrie D.J. Wiley-Blackwell Publishers, 2002

(b)Open sources of software and website:

1. Students can refer to video lectures available on the websites including NPTEL.
2. Students can refer to the website (https://sdgs.un.org) for Sustainable Development and (https://www.gcpcgujarat.org.in) for Cleaner Production concept.

List of suggested activities for Problem based Learning:

Sl. No.	Activity	No. of hours	Total hours claimed	Evaluation criteria
1	Assignments on topics based on sustainable energy technology	Five assignments (2h each)	**10**	Quality of submitted assignment.
2	Literature Review: Review 3–5 research papers on non-renewable energy, energy management, emerging technologies and other related topics and prepare a report.	Literature review: 5h Report preparation: 5h	**10**	Relevance of papers, depth of research papers reviewed, technical analysis, Quality of report.
3	Developing posters, charts or PowerPoint presentations on topics related to emerging sustainable technologies.	Study and in-depth analysis of content: 4h Preparation and presentation of visual content: 1h	**5**	Quality of topic researched and presentation.
4	Technical video based learning related to subject and report preparation.	Duration of video: 4h, report preparation: 1h.	**5**	Quality of technical video based learning and report prepared.
5	Energy audit of an industry.	Energy audit report	**10**	Quality of the energy audit work and report submitted.
6	Self-learning on-line course.	Min. Duration of the course should be 10h	**10**	On submission of certificate of completion.
7	Development of physical model	Model development: working 10h, non-working 5h	**5/10**	Quality of model developed and explanation.
8	Industry visit	Industry visit: 5h, Report preparation: 5h	**10**	Quality of observations made and detail report

				submitted.
9	Case study	Data collection, case analysis: 5h Report preparation: 5h	**10**	Understanding and analysis of the selected case and report submitted.

- Above activities are suggestive, faculty can choose any of these activities.
- The number of hour is suggestive. Faculty can sub-divide the number of hours based on the activity. However, the total number of hours is fixed.
- All records pertaining to the evaluation and assessment of self-learning activities must be properly maintained and preserved at the institute level. These records should be made available to the university upon request.
- Institutes are encouraged to utilize digital platforms, such as Microsoft Teams, for effective recordkeeping and to ensure transparency in the evaluation and assessment of problem based learning.

List of Tutorials:

Sr No.	Unit	Topic Coverage	Key Subtopics	Learning Outcome
1	1	Principles of Green Chemistry	Definition, Objectives, 12 Principles, Green Chemistry vs Green Engineering	Understand foundation of green chemistry
2		Process Intensification	Definition, Objectives, Microreactors, Reactive Distillation	Understand modern compact process systems
3	2	Green Oxidation & Photochemical Reactions	Green oxidation and photochemical reactions with suitable examples	Learn sustainable synthesis methods
4		Microwave & Ultrasound Synthesis	Principles, Cavitation, Industrial Applications	Understand energy-efficient synthesis
5		Green Solvents & Reagents	Water, Supercritical CO_2, Ionic Liquids, Bio-solvents	Identify eco-friendly alternatives
6		Green Nanotechnology	Nanocatalysts, Waste minimization, Industrial Applications	Learn advanced catalytic strategies
7	3	Pollution in Major Industries	Polymer, Textile, Pharma, Dye, Pesticide, WWTP	Understand pollution sources
8		Industrial Pollutants	Air, Water, Solid, Hazardous pollutants, Environmental impacts	Classify pollutants & impacts
9		Green Industrial Approaches	Cleaner Production, Recycling, Energy Efficiency, ZLD	Apply sustainable industrial strategies

10	4	Sustainable Development Concepts	SD Definition, 3 Pillars, Equity, Circular Economy	Understand sustainability framework
11		Sustainable Development Goals (SDGs)	17 SDGs, Industrial relevance, Challenges	Connect SDGs with industry
12	5	Cleaner Production (CP)	CP Concept, CP Tools, Relation of CP and EMS	Understand CP methodology
13		CP Case Studies	Water reuse, ETP modernization, Nitrogen recovery, Fluoride removal	Analyze real industrial cases
14	6	Green Productivity & Emerging Technologies	Implementation of the practical applications of Green Emerging Technologies and Sustainable Development.	Explore practical application of future technologies
15		Practical Implementation & Compliance	Corporate Responsibility, Green Laws, Implementation Challenges	Understand regulatory & practical aspects

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