GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: Chemical Engineering
Subject Code: BE05005041
Subject Name: Bio-Chemical Engineering

w.e.f. Academic Year:	2024-25
Semester:	5
Category of the Course:	Professional Elective Course - 1

Prerequisite:	Basic knowledge related to Biochemistry, Microbiology, Material & Energy, Balances, Chemical Engineering fundamentals
Rationale:	Biochemical Engineering plays a vital role in addressing global challenges related to healthcare, food security, clean water, sustainable energy, and climate change. This course provides fundamental and applied knowledge of biochemical reaction engineering, bioprocess design, bioreactors, downstream processing, and sustainable bioprocess development. The syllabus is aligned with IIT-level rigor and embeds the United Nations Sustainable Development Goals (SDGs) throughout theory, examples, and applications.

Course Outcome:

After Completion of the Course, Students will be able to:

No	Course Outcomes
01	Explain the scope, evolution, and role of biochemical engineering in food, pharmaceutical, energy, and environmental sectors, and interpret the principles of sustainable bioprocess development within the framework of the circular bioeconomy.
02	Apply enzyme kinetics and microbial growth models to analyze enzyme-catalyzed and microbial bioprocesses fermentation in batch and continuous reactors for sustainable and green manufacturing.
03	Analyze bioreactor types, operating modes, oxygen transfer, heat and mass transfer, and scale-up criteria to ensure efficient and industrially viable bioprocess systems.
04	Design integrated downstream processing and sustainable bioprocess applications considering life cycle assessment, waste minimization, and regulatory aspects.

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 to Biochemical Engineering & Sustainable Bioprocesses:** Scope and evolution of biochemical engineering; role of biochemical engineers in food, pharmaceutical, energy, and environmental sectors; overview of bioprocess industries; comparison of chemical and biochemical processes; sustainable bioprocess development with emphasis on circular bioeconomy.	5	15
2	**Enzyme Kinetics and Biochemical Reaction Engineering:** Enzyme classification and industrial significance; enzyme kinetics and Michaelis–Menten model; effects of pH, temperature, and substrate concentration; enzyme inhibition and activation; immobilized enzymes and their kinetics; batch and continuous enzyme reactors; applications of enzymes in green chemistry and sustainable manufacturing.	13	25
3	**Fermentation technology and Microbial Growth Kinetics:** Industrial fermentation and role of microorganisms; microbial growth phases; media preparation and components; sterilization principles and methods; microbial growth kinetics (Monod, substrate inhibition); yield coefficients and maintenance energy; batch, fed-batch, and continuous fermentation; oxygen transfer and aeration (OTR, OUR, kLa); agitation and aeration systems in fermenters.	9	20
4	**Bioreactor Design and Scale-Up:** Types of bioreactors (stirred tank, airlift, packed bed, fluidized bed); biochemical reactor design considerations; heat and mass transfer limitations; oxygen transfer coefficient (kLa); scale-up criteria and challenges; energy efficiency and process safety; industrial bioreactor design examples.	9	20
5	**Downstream Processing, Sustainable Bioprocess Applications:** Importance, scope, and cost of downstream processing; cell harvesting (filtration, centrifugation); cell disruption; membrane separations; chromatographic purification; waste minimization, solvent recovery, and resource efficiency; biopharmaceutical production; biofuels and bioenergy; environmental biotechnology (wastewater treatment, bioremediation); life cycle assessment (LCA); ethical, safety, and regulatory aspects.	9	20

Course aligned with SDGs 4, 6, 7, 8, 9, 12, 13, and 17 through sustainable biochemical engineering and circular bioeconomy practices.

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
10	20	25	25	20	**0**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze; E: Evaluate and C: Create and above Levels (Revised Bloom's Taxonomy)

- **Problem based activity can include the following:**

Sr. No.	Description (Problem-Based)	No. of Hours	Total Hrs
1	**Problem-based Technical Video Analysis** Students will analyze an industrial video related to fermentation, bioreactor operation, or downstream processing to identify a technical or sustainability-related problem and propose possible engineering solutions.	Video – 1 hr Problem identification and solution – 2hrs	3
2	**Numerical Problem-Based Assignment** Students will solve numerical problems related to microbial growth kinetics, enzyme kinetics, bioreactor performance, or downstream processing efficiency and interpret results for process improvement.	2 hrs	2
3	**Research Paper–Based Problem Analysis** Students will study a recent research paper related to biochemical engineering, identify the core problem addressed, analyze key parameters, and evaluate the proposed solution.	Reading paper – 2 hrs Problem identification and solution – 2hrs	4
4	**Case Study on Industrial/Societal Problem** Students will analyze a real-world case study related to food fermentation, biopharmaceutical production, bioenergy, or wastewater treatment and suggest process-level improvements.	One case study for 3 hrs	3
5	**Mini Design / Optimization Problem** Students will formulate and solve a small design or optimization problem related to bioreactor operation, fermentation strategy, or sustainable downstream processing.	One design for 3 hrs	3
Max. Hours to be allotted			**15**

Reference Books:

1. Bailey, J.E. and Ollis, D.F., *Biochemical Engineering Fundamentals*, 2nd Ed., McGraw-Hill, New York.
2. Shuler, M.L. and Kargi, F., *Bioprocess Engineering: Basic Concepts*, 2nd Ed., Prentice Hall.
3. Doran, P.M., *Bioprocess Engineering Principles*, Academic Press.
4. Stanbury, P.F., Whitaker, A. and Hall, S.J., *Principles of Fermentation Technology*, 3rd Ed., Elsevier.
5. Coulson and Richardson, *Chemical Engineering*, Vol. 6: Chemical Engineering Design, Butterworth-Heinemann.

List of Experiments: *(Minimum 08 experiments to be performed)*

1. **Natural Fermentation (Lactic Acid Fermentation of Cabbage)** – To study traditional food fermentation and lactic acid production.
2. **Primary Screening of Amylase-Producing Microorganisms (Starch Agar Plate Method)** – To isolate and identify enzyme-producing microorganisms.
3. **Primary Screening of Antibiotic-Producing Microorganisms (Nutrient Agar Plate Method)** – To detect antimicrobial activity of soil microorganisms.
4. **Primary Screening of Organic Acid-Producing Microorganisms (Phenol Red Agar Plate Method)** – To identify acid-producing microbes using indicator media.
5. **Gram Staining of Microorganisms** – To study morphology and classification of bacteria.
6. **Sugar Estimation by Cole's Oxidation–Reduction Method** – To quantitatively estimate reducing sugars.
7. **Bacteriological Culture Media Preparation, Sterilization and Cultivation** – To perform media formulation, sterilization, and aseptic cultivation of microorganisms.
8. **Sterility Test of Pharmaceutical Product (Direct Inoculation Method)** – To evaluate sterility and contamination in pharmaceutical products.
9. **Fermentative Production of Ethanol Using Yeast** – To study industrial alcohol fermentation and product formation.
10. **Measurement of Oxygen Transfer Rate (OTR) by Sodium Sulfite Method** – To evaluate aeration efficiency in bioreactors.
11. **Effect of Substrate Concentration on Enzyme Kinetics (Virtual Lab)** – To study the influence of substrate concentration on enzyme activity.
12. **Effect of Temperature on Enzyme Kinetics (Virtual Lab)** – To study the effect of temperature on enzyme activity.
13. **Bacterial Growth Curve Analysis (Virtual Lab)** – To analyze microbial growth patterns under controlled conditions.

Major Equipment:

Laboratory fermenter / bioreactor, Shaker incubator, Autoclave, Centrifuge, pH meter and DO meter, Laminar air flow cabinet.

List of Open Source Software/learning website:

1. NPTEL video lectures on Biochemical Engineering, Bioprocess Engineering, Fermentation Technology, and Downstream Processing.
2. Open-source simulation tools and spreadsheets for enzyme kinetics, microbial growth, and bioreactor modelling.
3. Online databases and learning platforms for bioinformatics and biochemical process analysis.
4. Students may develop simple computational models or programs for solving biochemical engineering problems.

Suggested Activities for Students: Preparation of power-point slides incorporating videos, animations, schematics, and process flow diagrams for better understanding of biochemical engineering concepts. The faculty will allocate units or sub-topics to groups of students so that the entire syllabus be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide.

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