GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: Biotechnology
Subject Code: BE04004021
Subject Name: Bio-Reaction Engineering

w. e. f. Academic Year:	**2024-2025**
Semester:	**4**
Category of the Course:	**Professional Core Course**

Prerequisite:	Bioprocess Calculations, Biochemical Thermodynamics
Rationale:	This subject equips students with skills to design, optimize, and scale up bioprocesses for industries like pharmaceuticals, biofuels and food, combining biology, chemistry, and engineering principles. It enhances understanding of bioreactor operation, mass transfer, and control strategies for efficient biomanufacturing.

Course Outcomes:

Sr. No.	CO statement	Marks% weightage
CO-1	Understand the kinetics and mechanism of chemical and biochemical reactions	15
CO-2	Classify bioreactors and estimate Monod's parameters	15
CO-3	Design batch, continuous flow, and fed batch reactors for enzymatic reaction	25
CO-4	Understand scale up concepts for bioreactor	25
CO-5	Understand bioprocess plant design and process economics	20

Teaching and Examination Scheme:

Teaching / Learning Scheme (in Hours per semester)					Total Credits	Assessment Pattern and Marks					Total Marks
						Theory		Tutorial / Practical			
L	T	P	PBL*	Total no of hours per semester		ESE (E)	PA / CA (M)	PA/ CA (I)	PBL (I)	ESE (V)	
45	0	30	45	120	4	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

Content:

Sr. No.	Content	Total Hrs
1	**Introduction:** From traditional bioprocess design to systems biology approaches. Fundamentals of reaction types and reaction order. The effect of temperature on reaction rates (Arrhenius equation and activation energy concepts). Microbial growth kinetics: Monod model, substrate inhibition, and maintenance energy concepts. Batch reactor data interpretation for reversible and irreversible reactions; constant volume batch reactor modeling; application of integral and differential methods of kinetic data analysis. Introduction to structured and unstructured models for microbial growth.	10
2	**Bioreactor Systems:** Definitions and fundamental differences between chemical reactors and bioreactors. Classification of bioreactors: stirred-tank, airlift, packed-bed, fluidized-bed, bubble column, membrane bioreactors, photobioreactors. Reactor configurations and operation modes: batch, fed-batch, continuous. Description of a conventional bioreactor: vessel components, agitation, aeration systems, instrumentation and control systems, sensors (pH, DO, temperature). Design and construction criteria of bioreactors: material selection (hygiene, corrosion, pressure), aseptic operations, sterilization (SIP/CIP systems). Residence time distribution (RTD) analysis, concentration profiles, temperature distribution in bioreactors. Models of non-ideal reactors: dispersion model, tanks-in-series model, and compartmental modelling. Introduction to Computational Fluid Dynamics (CFD) for simulating bioreactor performance.	15
3	**Design of Bioreactors:** Design considerations for isotropic and non-isotropic systems. Design equations for enzyme reactors (immobilized and free enzymes). Kinetic modelling for batch microbial growth. Design of plug flow reactors (PFR) and continuous stirred-tank reactors (CSTR), including concepts of washout and dilution rate. Biomass recycle and retention strategies: membrane bioreactors, cell recycle systems. Design and analysis of multiple CSTRs in series (with and without biomass recycle). Estimation of kinetic and stoichiometric parameters through laboratory and pilot studies. Role of mixing, shear stress, and oxygen transfer in industrial bioprocesses; introduction to scale-up criteria (constant tip speed, constant volumetric power input, constant kLa). Advanced mixing strategies for high-viscosity fermentation and non-Newtonian fluids.	10
4	**Bioprocess Plant Design** General considerations for bioprocess plant layout and equipment sizing. Mass and energy balance development for bioprocesses. Process flow diagram (PFD)	10

	and piping & instrumentation diagrams (P&ID) creation. Materials of construction: selection for biocompatibility, durability, and regulatory compliance (GMP standards). Design and specification of heat transfer (e.g., heat exchangers) and mass transfer equipment (e.g., gas spargers, distillation columns) for bioprocesses. Utility systems: steam generation, clean-in-place (CIP), sterilize-in-place (SIP), compressed air, and water purification systems. Introduction to process control systems: SCADA, distributed control systems (DCS), and bioreactor automation. Bioprocess economics: cost estimation, return on investment (ROI), life-cycle assessment (LCA). Risk analysis and safety considerations: biosafety levels (BSL), containment strategies, HAZOP analysis. Introduction to regulatory aspects: Good Manufacturing Practices (GMP), validation and qualification of bioprocess plants, regulatory guidelines from FDA, EMA.	
	TOTAL	**45**

Suggested Specification table with Marks (Theory): (For B.E. only)

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

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

Reference Books:

1. Octave Levenspiel, Chemical Reaction Engineering, A Wiley- interscience Publication, 2004, 3rd Edition
2. James E. Bailey, David F. Ollis, Biochemical Engineering Fundamentals, Mc Graw Hill, 1986, 2nd Edition.
3. Jens Nielsen, John Villadsen, Gunnar Lidén, Bioreaction Engineering Principles, Kluwer Academics /Plenum publishers, 2002, 2nd Edition
4. Paulin M. Doran, Bioprocess Engineering Principles, Elsevier Science & Technology Books, 2013, 2nd Edition

List of Experiments / Practical Demonstrations

1. Study of batch growth kinetics of *E. coli* and determination of μmax. Nonlinear curve fitting and growth modeling.
2. Determination of Monod constants (Ks and μmax) using substrate concentration data. Model fitting & interpretation of biological parameters.
3. Determination of oxygen transfer coefficient (kLa) using dynamic gassing-out method. Relate oxygen transfer

with agitation and aeration.
4. Study of enzyme-catalyzed reaction kinetics (Michaelis-Menten model). Analyze enzyme saturation curve.
5. Residence Time Distribution (RTD) study in Continuous Stirred Tank Reactor.Use tracer response to evaluate reactor efficiency.
6. Temperature effect on enzyme activity (Arrhenius plot). Evaluate activation energy and stability range.

Major Equipment
1. Bench-top fermenter / bioreactor
2. DO & pH probes
3. Spectrophotometer
4. Air supply system with flowmeter
5. Data logger

Open-Source Software / Learning Websites
1. NPTEL: Biochemical Engineering
2. Bioreactor simulator (BioReact, Virtual Labs - IIT Delhi)
3. Wolfram Mathematica (Student edition)

List of suggested activities for Problem Based Learning:
1. Simulation of Monod growth curve using Excel or Python.
2. Virtual lab practice for fed-batch bioreactor.
3. Group presentation on scale-up parameters (kLa, mixing).

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