GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3170407
BIOCHEMICAL ENGINEERING
7th Semester

Type of course: B.E. (Biotechnology)

Prerequisite: Basic Concepts of Transport Phenomena (Mass transfer and heat transfer) and Reaction kinetics for bioreactor.

Rationale: This subject is designed to help students understand different unit operations used in the manufacturing, recovery, purification and design (including control) of biological products. It will give exposure to required processes. The use of software makes it attractive to cater the need of industrial applications.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
4	0	2	5	70	30	30	20	150

Course Contents:

Sr. No.	Topics	Teaching Hours
1	[A]**What is A Bioprocess Engineer?:** Biotechnology and Bioprocess Engineering, Biologists and Engineers Differ in Their approach to research, How biologists and Engineers Work together [B] Overview of how cells work and how cells grow [C] How cellular information is altered?	3
2	**[A] Material Balances** Thermodynamic Preliminaries, System and Process, Steady State and Equilibrium, Law of Conservation of Mass, Types of Material Balance Problem, Simplification of the General Mass Balance Equation, Procedure for Material-Balance Calculations Stoichiometry of Growth and Product Formation, Growth Stoichiometry and Elemental Balances, Electron Balances, Biomass Yield, Product Stoichiometry, Theoretical Oxygen Demand, Maximum Possible Yield **[B] Energy Balances** Basic Energy Concepts, Units, Intensive and Extensive Properties, Enthalpy, General Energy-Balance Equations, Special Cases, Enthalpy Calculation Procedures, Change in Temperature, Change of Phase, Mixing and Solution, Heat of Combustion, Heat of Reaction-basic idea, Energy-Balance Equation for	6

	Cell Culture, Fermentation Energy-Balance	
3	**[A] Fluid Flow and Mixing** Classification of Fluids, Fluids in Motion, Streamlines, Reynolds Number, Hydrodynamic Boundary Layers, Boundary-Layer Separation, Viscosity, Momentum Transfer, Non-Newtonian Fluids, Two-Parameter Models, Time Dependent Viscosity, Viscoelasticity, Viscosity Measurement, Cone-and-Plate Viscometer, Coaxial-cylinder Rotary Viscometer, Impeller Viscometer, Use of Viscometers with Fermentation Broths, Factors Affecting Broth Viscosity, Mixing- Mixing Equipment, Flow Patterns in Agitated Tanks, Mechanism of Mixing, Assessing Mixing Effectiveness Power Requirements for Mixing, Ungassed Newtonian Fluids, UnGassed Non-Newtonian Fluids, Gassed Fluids, Scale-Up of Mixing Systems, Improving Mixing in Fermenters, Effect of Rheological Properties on Mixing, Role of Shear in Stirred Fermenter, Introduction Between Cells and Turbulent Eddies, Bubble Shear **[B] Mass Transfer** Molecular Diffusion, Diffusion Theory, Analogy Between Mass, Heat and Momentum Transfer, Role of Diffusion in Bio processing, Role of Transport processes in Bioreactors, Film Theory, Convective Mass Transfer, Liquid-Solid Mass Transfer, Liquid-Liquid Mass Transfer. Gas-Liquid Mass Transfer, Oxygen Uptake in Cell Cultures, Factors Affecting Cellular Oxygen Demand, Oxygen Transfer from Gas Bubble to Cell, Oxygen Transfer in Fermenter, Bubbles, Sparging, Stirring and Medium Properties, Antifoam Agents, Temperature, Estimating Oxygen Solubility, Effects of Oxygen Partial Pressure, Effect of Temperature, Effect of solutes, Measurement of k_L a, Oxygen-Balance Method, Dynamic Method, Sulphite Oxidation, Oxygen Transfer in Large Vessels **[C]** Basic concepts in heat transfer with reference to stoichiometry [D] overview of practices in carrying out unsteady state material and energy balance	**8**
4	**Homogeneous Reactions** Basic Reaction Theory, Reaction Thermodynamics, Glucose isomerisation, Reaction Yield, Reaction, Reaction rate, Reaction Kinetics, General Reaction Kinetics for Biological system, Zero-Order Kinetics, Michaelis-Menten Kinetics, Effect of Conditions on Enzyme Reaction Rate, Michaelis-Menten plot, Lineweaver-Burk plot, Eadie-Hofstee plot, Langmuir plot, Kinetics of Enzyme Deactivation. Yields in cell Culture, Overall and Instantaneous Yields, Theoretical and Observed Yields, Cell Growth Kinetics, Batch Growth, Balanced Growth, Effect of Substrate Concentration, Production Kinetics in cell Culture. Kinetics of Substrate Uptake in cell culture, Substrate Uptake in the presence and absence of Product Formation, Effect of Culture Conditions on Cell Kinetics, Product Yield from Biomass and Substrate, Kinetics of Cell Death.	**6**

	Overview of heterogeneous reactions.	
5	**Bioreactor Engineering** Bioreactor Configuration , Stirred Tank, Bubble Column, Airlift Reactor, Stirred and Air-Driven Reactors: Comparison of Operating Characteristics, Packed Bed, Fluidised Bed, Trickle Bed, Practical Considerations for Bioreactor Construction, Aseptic Operation, Fermenter Inoculation and sampling, Sparger Design, Evaporation Control. Batch operation of a Mixed Reactor, Enzyme reaction, Cell culture, Total time for Batch Reaction Cycle, Fed-Batch operation of a Mixed Reactor, Continuous Operation of a Mixed Reactor, Chemostate with Immobilised Cells and Cell Recycle-overview. Design and analysis of biological reactors: Sterlization bioreactors-batch and continuous), multiphase bioreactors, Animal and plant cell reactor technology. Fermentation systems, Scale up and scale-down processes, Aseptic operations of bioreactor and ancillaries. Sterilization, Batch Heat Sterilization of Liquids, Filter Sterilization of Liquids, Sterilization of Air.	**16**
6	Overview of upstream processing, media formulation. **Monitoring and control of bioprocesses:** Control of Bioprocess. Methods of on-line and off-line bio-mass estimation. **Flow injection analysis:** Introduction, principle, working, applications. **Biosensor Technology:** Principles, Types, elements, characteristics, applications.	**12**
7	Modeling and simulations: Modelling and simulations- Basics, Types of models, Dynamic modelling of fermentation systems, Case studies of bioprocesses (including plasmid stability), Applications through reading research papers in this area. Dynamic simulation of batch, fed batch, steady and transient culture metabolism. MATLAB-SIMULINK software packages- introductory level. Introduction to softwares related to process engineering /optimization, fermentation control.	**10**
8	Bioprocess economics, Economics of downstream processing in Biotechnology, cost-cutting strategies.	**3**

Suggested Specification table with marks (Theory):

Distribution of Theory Marks					
R Level	**U Level**	**A Level**	**N Level**	**E Level**	**C Level**
8	12	20	10	8	12

Legends: R= Remembrance**; U=** Understanding**; A=** Application**; N =** Analyze**; E =** Evaluate; **C** = Create and above Levels **(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.

Text Books:

1. Bioprocess Engineering- Basic Concepts; M.L. Shuler and F. Kargi, second edition, PHI pvt. Ltd. [Unit 1]
2. Bioprocess Engineering Principles by - Doran P.M., Elsevier Science and Technology Publishers, 1995. [Unit 2-5]
3. Biocehmical engineering fundamentals, James Bailey, David Ollis, TATA McGraw-Hill, second edition [Unit 8]
4. Principles of Fermentation Technology, by Whitaker, Peter F Stanbury, S. Hall and A. Whitaker, Publisher: Butterworth-Heinemann; 2nd edition

Course Outcomes:
Students should be able to

Sr. No.	CO statement	Marks % weightage
CO-1	Discuss the role of Biochemical Engineer in Industry.	4
CO-2	Evaluate the efficiency of bioprocesses by calculating the material and energy balances and realize the transport processes to biological reactors	21
CO-3	Choose correct system of bioreactor from homogeneous and heterogeneous modes	10
CO-4	Compare designs of bioreactors and its operating conditions.	25
CO-5	Apply the knowledge of methods of process monitoring, simulation and economics in bioprocesss industry	40

LIST OF PRACTICALS:

1. To get familiar with the application of biochemical kinetics simulation software.
2. Carry out analysis & interpretation through time course simulation & steady state analysis using biochemical kinetics simulation software
3. To optimize ethanol from *S.Cerevisiae* using simulation software copasi through study of kinetics
4. To Study MATLAB application for engineering tools with practices in matrices, plotting graphs and writing program for simple calculations

5. To generate results of control process for a given input set of controllers by SIMULINK package
6. To study any one fermentation control software and notice the parameters and variables with its output
7. To draw the growth kinetics of feed batch culture by constant, linear and exponential feeding patterns
8. To plot the growth curve of *E.coli* strain and to estimate the specific growth rate and biomass yield coefficient from the substrate utilization data
9. To measure oxygen absorption rate by iodine titration method (OAR) under the effect of static and shaking condition, with varying sample volume (at same flask size) and flask size (at same sample volume)
10. To determine the oxygen uptake rate by sodium sulphate titration method

Open Ended Problem:
Some suggested projects are listed below:

1. To design a reactor system for batch operation.
2. To design a biochemical process showing optimization features being used.

List of Open Source Software/learning website:
Students can refer to video lectures available on the websites including NPTEL (SWAYAM).
Students can refer to the virtual labs/ softwares which are available free for academic purpose (for example, IITB-NMICT-FOSSE).