GUJARAT TECHNOLOGICAL UNIVERSITY

BRANCH NAME: Bio-Technology (04)
SUBJECT NAME: Biochemical Engineering-I
SUBJECT CODE: 2170407
B.E. 7th SEMESTER

Type of course: **Bio Technology- Core subject**

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

Rationale: This subject is an integration of chemical engineering with biological systems. It deals with kinetics of biological reactions, mass and heat transfer concepts and transport phenomena occuring within biological reactors.

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)	
					PA	ALA	ESE	OEP		
4	0	0	4	70	10	20	0	0	0	100

Content:

Sr. No.	Content	Total Hrs	% Weightage
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, Bioprocesses: Regulatory Constraints Suggestions for Further Reading Problems **[B] AN OVERVIEW OF BIOLOGICAL BASICS:** Are All Cells the Same? –(Microbial Diversity, Naming Cells, Viruses, Prokaryotes, Eukaryotes), Cell Construction, cell nutrients **[C] ENZYMES:** How enzymes Work? Enzyme Kinetics, Immobilized Enzyme Systems, Large-scale Production of Enzymes, Medical and Industrial Utilization of Enzymes **[D] HOW CELLS WORK:** The Central Dogma, DNA	**8**	12

	Replication: Preserving and Propagating the Cellular Message, Transcription, Genetic Code, Translation, Posttranslational Processing: Making the Product Useful. Metabolic Regulation, How the Cell Senses Its Extracellular Environment **[E] HOW CELLS GROW : (overview only)** Batch Growth, Quantifying Growth Kinetics, How Cells Grow in Continuous Culture(Some Specific Devices for Continuous Culture, The Ideal Chemo stat, The Chemo stat as a Tool, Deviations from Ideality) **[F] How cellular information is altered?**		
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, Material-Balance Worked Examples, Material Balances With Recycle, By-Pass and Purge Streams 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 at Non-Standard Conditions Heat of Reaction for Process with Biomass Production, Thermodynamics of Microbial Growth, Heat of Reaction with Oxygen Not the Principal Electron Acceptor, Energy-Balance Equation for Cell Culture, Fermentation Energy-Balance Worked Examples	**14**	22

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, Cell Concentration , Cell Morphology, Osmotic Pressure, Product and Substrate Concentrations Mixing, Mixing Equipment, Flow Patterns in Agitated Tanks, Radial-flow impellers, Axial-flow Impellers, 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	**14**	22
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, Determining Enzyme Kinetic Constants	**14**	22

	From Batch data, Michaelis-Menten plot, Lineweaver-Burk plot, Eadie-Hofstee plot, Langmuir plot, Direct liner 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, Growth Kinetics with Plasmid Instability, Production Kinetics in cell Culture, Product Formation Directly Coupled with Energy Metabolism, Product Formation Indirectly Coupled with Energy Metabolism, Product Formation Not Coupled With Energy Metabolism, Kinetics of Substrate Uptake in cell culture, Substrate Uptake in the Absence of Product Formation, Substrate Uptake in the of Product Formation, Effect of Culture Conditions on Cell Kinetics, Determining Cell Kinetic Parameters from Batch data, Rates of growth , Product formation and Substrate Uptake, μ_{max} and k_s , Effect of Maintenance on Yields, Observed Yields, Biomass Yield from Substrate, Product Yield from Biomass, Product Yield from Substrate, Kinetics of Cell Death		
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, Enzyme Reaction, Cell Culture, Chemostate with Immobilised Cells and Cell Recycle-overview. Evaluation of Kinetic and Yield Parameters in Chemostate Culture. Sterilization, Batch Heat Sterilization of Liquids, Filter Sterilization of Liquids, Sterilization of Air. Overview of upstream processing, media formulation.	**14**	22

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	**10**	**10**	**15**	**15**	**10**

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and 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]

Reference Books:

3. Biochemical Engineering Fundamentals by James E. Bailey, David F. Ollis, Publisher: McGraw-Hill Inc.,US, 2nd Edition.
4. Principles of Fermentation Technology, by Whitaker, Peter F Stanbury, S. Hall and A. Whitaker, Publisher: Butterworth-Heinemann; 2nd edition
5.

Course Outcome:

After learning the course the students should be able to:

1. Develop major understanding of biological cellular systems
2. Evaluate kinetics of biological reactions with the basic understanding in heat and mass transfer
3. Understand transport phenomena in biological reactors
4. Apply the concepts of various unit operations in downstreaming of biological products.

List of Open Source Software/learning website:

Students can refer to video lectures available on the websites including NPTEL. Students can refer to the CDs which are available with some reference books

ACTIVE LEARNING ASSIGNMENTS:

Preparation of power-point slides, which include videos, animations, Pictures, graphics for better understanding theory – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus of Bioprocess and Biochemical Engineering is covered.