Semester: 6	
Course: Major 3	
Paper Title: Bioprocess Technology	
Paper code: C3BT230631T	**Credits: 4**
Hours/week: 4	
Category: Core/MDC/SEC/VAC: Core	
Theory / Practical / Composite: Theory	
No of Modules: 2	

Course Overview:

- This is an advanced, application-oriented course that systematically integrates microbial physiology, biochemical reactions, and chemical engineering principles to elucidate the scientific basis and industrial implementation of large-scale biological production systems.
- The course gives a comprehensive introduction to industrial bioprocess technology, emphasizing the evolution of fermentation processes, selection and development of high-yielding microbial strains, and the role of producer microorganisms in the manufacture of bio-based products.
- It provides an in-depth understanding of upstream processing, including strain screening, genetic improvement, inoculum development, media formulation and statistical optimization, and sterilization, followed by detailed analysis of fermentation strategies such as batch, fed-batch, and continuous cultures, with quantitative treatment of microbial growth and fermentation kinetics, substrate utilization, and product formation in chemostat and turbidostat systems.
- The course critically examines bioreactor design and operation across laboratory, pilot, and industrial scales, highlighting stirred tank reactors and a few specialized bioreactors, oxygen transfer mechanisms, hydrodynamics, mixing, and aeration, supported by engineering concepts such as mass and energy balances, biomass yield coefficients, fluid flow behavior, and dimensionless numbers governing agitation and power consumption.
- Advanced topics include mass transfer phenomena, cellular oxygen demand, determination of volumetric mass transfer coefficients, and scale-up criteria with associated technical challenges.
- The curriculum further extends bioprocess applications to environmental and energy sectors through the scientific principles of municipal water and wastewater treatment, large-scale microbial bioethanol production, solid-state fermentation, and single cell protein (SCP) production.
- Collectively, the course develops a rigorous conceptual and quantitative foundation enabling students to analyze, design, optimize, and evaluate industrial bioprocesses central to modern Biotechnology, Bioenergy, and Environmental Bioprocess industries.

Course Outcome:

Module A

1. Remember Students will recall the fundamental concepts of Bioprocess Technology, including industrial fermentation systems, high-yielding microbial strains, components of fermentation technology including upstream processing, main fermentation and downstream processing, and the basic steps in the treatment of drinking water supplies and wastewater by municipalities, as well as in large-scale bioethanol production.

2. Understand Students will develop an understanding of the batch, fed-batch and continuous modes of bioreactor operation, growth and fermentation kinetics in these

culture systems (including turbidostat and chemostat), basic principles of operation of laboratory-, pilot-scale and production bioreactors and of a basic bioreactor design, types and components of different types of bioreactors, and the need of meeting cellular oxygen demand.
3. Apply Students will learn to apply growth and fermentation kinetics to real-world fermentation, wastewater treatment, and bioethanol and SCP production processes.
4. Analyze Students will analyze bioprocess performance by interpreting fermentation kinetics.
5. Evaluate Students will critically evaluate the different bioreactor configurations, solid-state and submerged fermentation systems, and microbial bioethanol production process, based on industrial feasibility, efficiency, and sustainability.
6. Create Students will be able to design integrated bioprocess workflows or conceptual process models integrating bioreactor design and operation for the production of industrially relevant biomolecules or biofuels.
Module B
1. Remember Students will remember the key terminologies related to applications of engineering principles in Bioprocess Technology, and the basic steps in large-scale SCP production.
2. Understand Students will develop an understanding of the oxygen transfer and mass transfer mechanisms, and engineering parameters governing bioprocess performance.
3. Apply Students will learn to apply Bioprocess engineering principles such as stoichiometric analysis, biomass yield calculations, kinetic modeling, mass and energy balance, fluid flow characteristics and mixing in bioreactors, Newtonian and Non-Newtonian fluids, Reynold's number, Froude's number, Agitation and Power number, media preparation and optimization (Plackett-Burman design), sterilization strategies and inoculum development to real-world fermentation, wastewater treatment, and bioethanol and SCP production processes.
4. Analyze Students will analyze bioprocess performance by evaluating mixing and mass transfer coefficients, assessing scale-up parameters, and diagnosing operational constraints with regard to scale-up in industrial bioprocesses.
5. Evaluate Students will critically evaluate the upstream procedures (including screening, strain improvement and preservation) and downstream processing strategies, and SCP production process, based on industrial feasibility, efficiency, and sustainability.
6. Create Students will be able to design integrated bioprocess workflows or conceptual process models integrating strain selection, scale-up criteria, and product recovery strategies for the production of industrially relevant biomolecules or biofuels.
Prerequisites: **Basic knowledge about Microbiology, Microbial Physiology, Biochemistry & Fermentative mode of microbial nutrition.**
SYLLABUS

UNIT/Module	CONTENT	HOURS or NUMBER OF CLASSES	CO Mapping	COGNITIVE LEVEL
MODULE A [35 marks]	**UNIT I: Introduction to Bioprocess Technology:** Introduction to bioprocess technology; industrial	2 classes/ week	CO1 – CO6	K1 – K6

	fermentation; concept of high-yielding strain; important producer microorganisms; range of bioprocess technology and its chronological development; components of fermentation technology (upstream processing, main fermentation including submerged and surface processes, downstream processing); principles of operation of batch, fed-batch and continuous bioreactors; growth kinetics in batch, fed-batch and continuous cultures (including turbidostat and chemostat); fermentation kinetics in batch, fed-batch and continuous cultures. **UNIT II: Bioreactor designs:** Design of bioprocess vessels; definition of bioreactors; different types of bioreactor vessels - laboratory, pilot-scale and production bioreactors, basic bioreactor design (STR model); introduction to oxygen requirement in bioprocess - significance of spargers, impellers, baffles; different types of culture/production vessels – air-lift, cyclone-column, bubble-column, packed-tower, membrane bioreactor, photo bioreactor, perfusion bioreactor, plug flow reactor, upflow anaerobic sludge blanket reactor. **UNIT III: Liquid waste management:** Treatment of municipal drinking water supplies; large-scale treatment of waste water by municipalities. **UNIT IV: Bioethanol production:** Large-scale microbial production of bioethanol.			

Module B [35 marks]	**UNIT V: Engineering principles in Bioprocess Technology:** Mass Balance and Energy Balance, Biomass yield, Theoretical oxygen demand; Fluid flow characteristics and mixing in bioreactors; Newtonian and Non-Newtonian fluids, Reynold's number; Froude's number, Agitation and Power number.	2 classes/ week	CO1 – CO6	K1 – K6
	UNIT VI: Mass transfer and scale up in bioprocessing: Types of mass transfer in bioprocessing; Cellular Oxygen Demand; Measurement of Mass Transfer Coefficient; Scale up – criteria of scale up, problems related to scale-up.			
	UNIT VII: Upstream processing in fermentation: Screening of producer microorganisms, strain improvement and preservation of industrial microorganisms, fermentation media preparation and optimization (Plackett-Burman design), Inoculum development and sterilization.			
	UNIT VIII: Downstream processing in fermentation: Product recovery and purification.			
	Unit IX: Solid-State Fermentation and Single Cell Protein production: Factors influencing SSF, Bioreactors used for SSF; Microbial SCP production.			
Text Books				
Theory text/references 1. Casida LE. (1991). Industrial Microbiology. 1st edition. Wiley Eastern Limited.				

2. Crueger W and Crueger A. (2000). Biotechnology: A textbook of Industrial Microbiology. 2nd edition. Panima Publishing Co. New Delhi.
3. Das HK. (2005). Text Book of Biotechnology. 2nd edition. Wiley Dreamtech India (P) Ltd.
4. Dubey RC. (2010 Reprint Edition). A Text Book of Biotechnology. S. Chand & Company Ltd.
5. Madigan MT, Martinko JM and Parker J. (2003). Brock Biology of Microorganisms.10th edition. Pearson / Benjamin Cummings.
6. Patel AH. (1996). Industrial Microbiology. 1st edition, Macmillan India Limited.
7. Salle AJ. (1974). Fundamental Principles of Bacteriology. 7th edition, 2005 27th Reprint. Tata McGraw-Hill.
8. Stanbury PF, Whitaker A and Hall SJ. (2006). Principles of Fermentation Technology. 2nd edition, Elsevier Science Ltd.
9. Waites MJ, Morgan NL, Rockey JS, Higton G. (2001). Industrial Microbiology - An Introduction. 2002 Indian Reprint Edition. Blackwell Publishing.
10. Willey JM, Sherwood LM, and Woolverton CJ. (2008). Prescott, Harley and Klein's Microbiology. 7th edition. McGraw Hill Higher Education.
11. P. M. Doran, "Bioprocess Engineering Principles," 2nd Edition, Academic Press, Waltham, 2013.

Evaluation: Theory (100)
CIA - 20 marks; Assignment [On Industrial Visit] – 05 marks; Attendance – 05 marks; Semester Exam- 70 marks

Paper Structure for Theory Semester Exam Module:

Module A (35 Marks)
- 1 Compulsory Question (objective type) – 5 marks
- Any 3 out of 5 questions; each of 10 marks, with sub-parts (not less than 1, not more than 5) - 3×10 = 30 marks

Module B (35 Marks)
- Any 2 out of 3 Questions of 10 marks each with sub-parts (not less than 1, not more than 5). 2×10 = 20 marks.
- Any 3 out of 5 questions; each of 5 marks, with subparts (not less than 1, not more than 5). 3×5 = 15 marks.

COURSE OUTCOMES (COS) AND COGNITIVE LEVEL MAPPING

COs	CO Description	Cognitive levels
	Module A	
CO1	**Remember** Students will recall the fundamental concepts of bioprocess technology, including industrial fermentation systems, high-yielding microbial strains, components of fermentation technology including upstream processing, main fermentation and downstream processing, and the basic steps in the treatment of drinking water supplies and wastewater by municipalities, as well as in large-scale bioethanol production.	K1
CO2	**Understand** Students will develop an understanding of the batch, fed-batch and continuous modes of bioreactor operation, growth and fermentation kinetics in these culture systems (including turbidostat and chemostat), basic	K2

	principles of operation of laboratory-, pilot-scale and production bioreactors and of a basic bioreactor design, types and components of different types of bioreactors, and the need of meeting cellular oxygen demand**.**	
CO3	**Apply** Students will learn to apply growth and fermentation kinetics to real-world fermentation, wastewater treatment, and bioethanol and SCP production processes.	K3
CO4	**Analyze** Students will analyze bioprocess performance by interpreting fermentation kinetics.	K4
CO5	**Evaluate** Students will critically evaluate the different bioreactor configurations, solid-state and submerged fermentation systems, and microbial bioethanol production process, based on industrial feasibility, efficiency, and sustainability.	K5
CO6	**Create** Students will be able to design integrated bioprocess workflows or conceptual process models integrating bioreactor design and operation for the production of industrially relevant biomolecules or biofuels.	K6
	Module B	
CO1	**Remember** Students will remember the key terminologies related to applications of engineering principles in Bioprocess Technology, and the basic steps in large-scale SCP production.	K1
CO2	**Understand** Students will develop an understanding of the oxygen transfer and mass transfer mechanisms, and engineering parameters governing bioprocess performance.	K2
CO3	**Apply** Students will learn to apply **B**ioprocess engineering principles such as stoichiometric analysis, biomass yield calculations, kinetic modeling, mass and energy balance, fluid flow characteristics and mixing in bioreactors, Newtonian and Non-Newtonian fluids, Reynold's number, Froude's number, Agitation and Power number, media preparation and optimization (Plackett-Burman design), sterilization strategies and inoculum development to real-world fermentation, wastewater treatment, and bioethanol and SCP production processes.	K3
CO4	**Analyze** Students will analyze bioprocess performance by evaluating mixing and mass transfer coefficients, assessing scale-up parameters, and diagnosing operational constraints with regard to scale-up in industrial bioprocesses.	K4
CO5	**Evaluate** Students will critically evaluate the upstream procedures (including screening, strain improvement and preservation) and downstream processing strategies, and SCP production process, based on industrial feasibility, efficiency, and sustainability.	K5
CO6	**Create** Students will be able to design integrated bioprocess workflows or conceptual process models	K6

	integrating strain selection, scale-up criteria, and product recovery strategies for the production of industrially relevant biomolecules or biofuels.	