SEMESTER S5

BIOPROCESS ENGINEERING

Course Code	**PCBBT502**	**CIE Marks**	40
Teaching Hours/Week (L: T:P: R)	3:1:0:0	**ESE Marks**	60
Credits	4	**Exam Hours**	2 Hrs.30 Min.
Prerequisites (if any)		**Course Type**	Theory

Course Objectives:

The student should be made to,

1. Provide the students with the basics of bioreactor engineering.
2. Develop bioengineering skills for the production of biochemical product using integrated biochemical processes.

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SYLLABUS

Module No.	Syllabus Description	Contact Hours
1	**Overview of bioprocess engineering:** Engineering perspective of fermentation processes, integrated bioprocessing- comparison of bioprocess engineering with biochemical engineering. **Kinetics of microbial growth and product formation:** - Batch growth curve- kinetics of exponential growth- implications of endogeneous and maintenance metabolism- death phase kinetics- yield and maintenance coefficients- classification of microbial products - growth associated, non-growth associated and mixed growth associated product formation- Leudeking Piret equation-influence of various environmental conditions such as temperature, pH, DO concentration, redox potential, DCO_2 concentration, ionic strength and substrate concentration on growth kinetics **Thermal death kinetics of cells and spores:** Survival curve- decimal reduction factor, Extinction probability-sterilization of culture medium-	11

	batch and continuous sterilization- design aspects- air sterilization- design of fibrous type filters.	
2	**Medium engineering for cell cultivation and bioreaction:** Technological concerns of medium design engineering in bioprocessing-design procedure for growth and production medium- stoichiometric design approach- bioorganic reaction medium engineering- Novel media. **Kinetic modelling of cell growth:** Model structure and complexity- different perspectives for kinetic representations sing models- prediction of specific growth rate using unstructured un-segregated models-Monod equation- Monod chemostat model- Models with growth inhibitors (substrate inhibition, product inhibition and inhibition by toxic compounds)- logistic equation- growth models for filamentous organisms-structured kinetic models- compartment models, metabolic models, cybernetic models. **Mass transfer in bioprocessing systems:** Gas liquid mass transfer- volumetric oxygen transfer coefficient, correlations (Cooper correlation, Richards correlation) – oxygen transfer mechanism- assessment of KLa- chemical method, dynamic differential gassing out method, dynamic integral gassing out method, oxygen balance method, enzymatic method- merits and demerits of each method. **Scale up and scale down of bioprocess systems**: Need for scale up and scale down- operating boundaries for aerated and agitated fermenters- scale up criteria for microbial cell processes- constant power input per unit volume, constant KLa, constant mixing quality constant impeller tip speed,	**11**
3	**Monitoring and Control of Bioprocesses:** Fermentation monitoring: Various physical, chemical and biological parameters measured or controlled in bioreactors-Physical and chemical sensors for fermentation medium and gases- online sensors for cell properties-offline analytical methods **Process control:** Open loop and closed loop control-direct regulatory control, cascade control of metabolism-programmed control- application of artificial intelligence in bioprocess control-knowledge based expert systems, neural networks (A brief overview of the above is only required). **Bioprocess modeling and simulation:** Structure of bioprocess models-	**11**

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	concept of balance domain- model validation using MATLAB- objectives and benefits of bioprocess simulation-simulation tools such as SIMULINK, Biopro Designer, Biotechnology Design Simulator and Bioprocess Simulator.	
4	**Immobilized cell systems:** Potential advantages of cell immobilization, methods of active and passive immobilization-diffusional limitations in immobilized enzyme systems-bioreactor considerations. **Bioprocess considerations in using plant and animal cell cultures:** Methods for cultivation of animal cells-requirements for culturing of animal cells-bioreactor design considerations- perfusion systems-products of animal cell cultures- -bioreactor considerations for suspension cultures, immobilized systems and organ cultures- products of plant cell cultures. **Medical applications of bioprocess engineering:** overview of tissue engineering-commercial tissue culture processes gene therapy using viral vectors-use of bioreactors as artificial hybrid organs and for mass production of cells for transplantation.	**11**

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Course Assessment Method
(CIE: 40 marks, ESE: 60 marks)

Continuous Internal Evaluation Marks (CIE):

Attendance	Assignment/ Microproject	Internal Examination-1 (Written)	Internal Examination- 2 (Written)	Total
5	**15**	**10**	**10**	**40**

End Semester Examination Marks (ESE)

In Part A, all questions need to be answered and in Part B, each student can choose any one full question out of two questions

Part A	Part B	Total
• 2 Questions from each module. • Total of 8 Questions, each carrying 3 marks **(8x3 =24marks)**	• Each question carries 9 marks. • Two questions will be given from each module, out of which 1 question should be answered. • Each question can have a maximum of 3 sub-divisions. **(4x9 = 36 marks)**	**60**

Course Outcomes (COs)

At the end of the course students should be able to:

	Course Outcome	Bloom's Knowledge Level (KL)
CO1	Design a fermentation process in a bioreactor	**K5**
CO2	Analyze the cell growth and product formation in different cultivation systems	**K4**
CO3	Design batch and continuous sterilization	**K5**
CO4	Perform modeling and simulation of bioprocess	**K3**

Note*: K1- Remember, K2- Understand, K3- Apply, K4- Analyse, K5- Evaluate, K6- Create*

CO-PO Mapping Table:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	3	2		1	2				2
CO2	3	3	2	2	2	1	1					2
CO3	3	3	2	2			1					2
CO4	3	3	2	2	1	1	2	2				2
CO5	3	3	2	3	2		1	2				2

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Text Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Bioprocess Engineering Principles	Pauline M Doran	Elsevier- Academic Press	Second, 2013
2	Biochemical Engineering Fundamentals	James. E.Bailey, David.F. Ollis	2nd Edition, McGraw Hill	2017
3	Bioprocess Engineering: Kinetics, Sustainability, and Reactor Design	Shijie Liu	Elsevier	2020

Reference Books				
Sl. No	**Title of the Book**	**Name of the Author/s**	**Name of the Publisher**	**Edition and Year**
1	Bioprocess Technology:Kinetics and Reactors	Anton Moser,	Springer Verlag	2012
2	Principles of Fermentation Technology	P. F. Stanbury, S. J. Hall and A. Whitaker	, 3 rd Edition, Elsevier	2016

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Video Links (NPTEL, SWAYAM…)	
Module No.	**Link ID**
1	https://archive.nptel.ac.in/courses/102/105/102105064/ https://nlinecourses.nptel.ac.in/noc22_bt19/preview