



# GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering

Level: UG

Branch: Biotechnology

Subject Code: BE05004021

Subject Name: Bioprocess Engineering

|                         |                          |
|-------------------------|--------------------------|
| w. e. f. Academic Year: | 2026-2027                |
| Semester:               | 5                        |
| Category of the Course: | Professional Core Course |

|               |                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Prerequisite: | Bioprocess Calculations , Microbiology                                                                                                                                                                                                                                                                                                                                                                                     |
| Rationale:    | Bioprocess Engineering integrates principles of biology, chemistry, and engineering to design and optimize processes that utilize living cells or enzymes for the production of valuable products such as pharmaceuticals, enzymes, biofuels, and food ingredients. This subject provides students with a strong understanding of microbial growth, fermentation technology, bioreactor design, and downstream processing. |

## Course Outcomes:

| Sr. No. | CO statement                                                                                  | Marks% weightage |
|---------|-----------------------------------------------------------------------------------------------|------------------|
| CO-1    | Understand the role of a bioprocess engineer and the kinetics of the growth of microorganisms | 20               |
| CO-2    | Comprehend different sterilization techniques for medium and air                              | 20               |
| CO-3    | Apply the principles of fluid flow in bioprocessing systems                                   | 20               |
| CO-4    | Understand the applications of heat and mass transfer in bioprocesses                         | 20               |
| CO-5    | Compare various types of bioreactors                                                          | 20               |

## Teaching and Examination Scheme:

| Teaching / Learning Scheme<br>(in Hours per semester) |   |    |     |                                         | Total<br>Credits | Assessment Pattern and Marks |                   |                      |            |            | Total<br>Marks |
|-------------------------------------------------------|---|----|-----|-----------------------------------------|------------------|------------------------------|-------------------|----------------------|------------|------------|----------------|
| L                                                     | T | P  | PBL | Total no<br>of hours<br>per<br>semester |                  | Theory                       |                   | Tutorial / Practical |            |            |                |
|                                                       |   |    |     |                                         |                  | ESE<br>(E)                   | PA /<br>CA<br>(M) | PA/<br>CA<br>(I)     | PBL<br>(I) | ESE<br>(V) |                |
| 45                                                    | 0 | 30 | 15  | 90                                      | 3                | 70                           | 30                | 20                   | 30         | 50         | 200            |

## Content:

| Sr. No. | Content                                                                                                                                                                           | Total Hrs |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1       | <b>Introduction to Bioprocessing:</b><br>Role of a bioprocess engineer, kinetics of microbial growth, substrate utilization, and product formation; Batch and continuous culture. | 5         |



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|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 2            | <b>Sterilization:</b><br>Media sterilization; kinetics of thermal death of cells & spores, design of batch and continuous thermal sterilization, sterilization of air and filter design, radiation and chemical sterilization.                                                                                                                                                                                                                                                                                         | 5         |
| 3            | <b>Biofluid mechanics:</b><br>Newtonian and non-Newtonian fluids, factors affecting broth viscosity, velocity distribution in laminar flow and turbulent flow, aeration and agitation, power requirement for gassed and un-gassed systems, Rate of mixing.                                                                                                                                                                                                                                                             | 5         |
| 4            | <b>Bioprocess Heat Transfer:</b><br>Modes of heat transfer, Steady-state and un-steady-state heat transfer, Heat transfer coefficients, Boiling and condensation heat transfer, Heat transfer equipment, Evaporation.                                                                                                                                                                                                                                                                                                  | 10        |
| 5            | <b>Mass Transfer in Bioreactors:</b><br>Theories of mass transfer, Gas-Liquid mass transfer, Measurement of KLa, Oxygen transfer methodology, Maximum cell concentration.                                                                                                                                                                                                                                                                                                                                              | 10        |
| 6            | <b>Applications of bioreactors:</b><br>On-line and off-line measurement in bioreactors, Various types of microbial and enzyme reactors. Scale-Up in Bioprocessing: Challenges and strategies in scaling up bioprocesses from laboratory to industrial scale, including issues related to heat and mass transfer, shear forces, and mixing. Bioprocess Economics and Cost Optimization: Analysis of the economic aspects of bioprocessing, including cost factors such as raw materials, energy consumption, and labor. | 10        |
| <b>TOTAL</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>45</b> |

## 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)**

## The syllabus of Advanced Power Electronics directly contributes to

|       |                                                                                                                                                                                                                                     |
|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SDG 3 | The syllabus supports the production of pharmaceuticals, vaccines, antibiotics, enzymes, and therapeutic biomolecules through fermentation and bioprocess technologies, contributing to improved healthcare and disease management. |
| SDG 6 | Concepts of microbial treatment, bioreactors, and downstream processing contribute to sustainable wastewater treatment, pollutant removal, and improved water quality management.                                                   |
| SDG 7 | Bioprocess engineering enables the production of renewable biofuels such as bioethanol and biogas through microbial fermentation, supporting clean energy                                                                           |



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|        |                                                                                                                                                                           |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|        | generation.                                                                                                                                                               |
| SDG 9  | The subject promotes innovation in bioreactor design, fermentation systems, scale-up strategies, and industrial biotechnology for sustainable industrial development.     |
| SDG 12 | Bioprocess engineering encourages sustainable production systems using microorganisms and enzymes to reduce waste generation and optimize resource utilization.           |
| SDG 13 | Green bioprocesses and environmentally friendly technologies contribute to reduction of industrial pollution and greenhouse gas emissions, supporting climate resilience. |

## Reference Books:

1. Paulin M. Doran, Bioprocess Engineering Principles, Elsevier Science & Technology Books, 2008, 2<sup>nd</sup> Edition
2. James E. Bailey, David F. Ollis, Biochemical Engineering Fundamentals, Mc Graw Hill, 2004, 2<sup>nd</sup> Edition
3. Michael Shuler, Fikret Kargi, Bioprocess Engineering Basic Concepts, Prentice-Hall India, 2006, 2<sup>nd</sup> Edition
4. Wolf. R. Vieth, Bioprocess Engineering: Kinetics, Mass Transport, Reactors and Gene Expression, A Wiley-Inter science Publication, 2009, 1<sup>st</sup> Edition
5. P F Stanbury and A Whitaker, Principles of fermentation technology, Pergamon press, 2005, 3<sup>rd</sup> Edition

## List of Experiments / Practical Demonstrations

1. Study of microbial growth kinetics
2. Determination of yield coefficients in batch fermentation
3. Oxygen transfer studies in bioreactors (k<sub>La</sub> determination)
4. Rheological behavior of fermentation broths
5. Operation of a continuous stirred tank bioreactor (CSTR)
6. Enzyme kinetics and inhibition studies
7. Downstream processing – cell disruption and product recovery
8. Fed-batch fermentation control (optional)

## Major Equipment

1. Bioreactor / Fermenter
2. pH meter
3. Dissolved oxygen meter
4. Spectrophotometer
5. Centrifuge

## Open-Source Software / Learning Websites

1. COPASI – Simulation of biochemical reaction networks and kinetics (free).  
<https://copasi.org>
2. GNU Octave / Scilab – For bioprocess modeling and numerical analysis.



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3. DWSIM – Open-source process simulator for chemical/biochemical processes.

<https://dwsim.org>

4. Python (NumPy, SciPy, Matplotlib) – For modeling bioprocess dynamics.

5. R (Bioconductor packages) – Data analysis and visualization in bioprocessing.

List of suggested activities for Problem-based Learning (PBL):

| Sr. No. | PBL Category                                                   | Name of the Activity                                                                                                                              | No. of Hours                                                      | Evaluation Criteria                                                                                                                                                                   |
|---------|----------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1       | Industry / Research Laboratory Visit                           | Visit to fermentation industry / biopharmaceutical industry / wastewater treatment plant / research laboratory related to bioprocessing           | Visit = 5 hrs, Report preparation = 5 hrs Total = 10 hrs          | Based on report submitted. Report should contain observations on fermentation process, bioreactor operations, sterilization systems, downstream processing, and process optimization. |
| 2       | Video Based Learning                                           | Technical video-based learning related to microbial kinetics, fermentation technology, bioreactors, mass transfer, and sterilization (MOOC/NPTEL) | Video duration = 5 hrs, Report preparation = 5 hrs Total = 10 hrs | Report/presentation based on learning outcomes and understanding of bioprocess engineering concepts.                                                                                  |
| 3       | Assignment / Technical Writing / Research Writing              | Numerical and theory-based assignments related to fermentation kinetics, sterilization calculations, heat transfer, and mass transfer             | 5 assignments × 2 hrs = 10 hrs                                    | Based on assignment quality, calculations, interpretation, and technical presentation.                                                                                                |
| 4       | Complex Problem-Solving Targeting Relevant SDGs / Mini Project | Design and comparative analysis of batch vs continuous fermentation system for bioethanol or enzyme production                                    | 15 hrs                                                            | Based on problem-solving approach, calculations, simulation/design, and technical feasibility.                                                                                        |
| 5       | Research Paper Review / Analysis                               | Review of SCOPUS-indexed research papers on microbial kinetics, oxygen transfer, bioreactor design, or downstream processing                      | 5 research papers = 20 hrs                                        | Based on critical analysis, summary, and understanding of technical parameters.                                                                                                       |
| 6       | Poster / Chart / PowerPoint Presentation                       | Preparation of poster/PPT on topics like Bioreactor Design, Oxygen Transfer, Sterilization, Fermentation Process                                  | 6 hrs                                                             | Based on technical depth, creativity, presentation quality, and communication skills.                                                                                                 |
| 7       | Micro Project                                                  | Working/non-working model                                                                                                                         | 10 hrs                                                            | Based on innovation, working                                                                                                                                                          |



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|    |                                      |                                                                                                                      |                                                                          |                                                                                |
|----|--------------------------------------|----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|    |                                      | of bioreactor, fermentation system, sterilization setup, or wastewater treatment bioprocess                          |                                                                          | principle, technical relevance, and evaluation.                                |
| 8  | Group Discussion / Quiz / Simulation | Group discussion on emerging areas such as AI in Bioprocess Engineering, Smart Bioreactors, Industrial Biotechnology | 1 hr each                                                                | Based on technical knowledge, participation, and communication.                |
| 9  | Case Study Analysis / Seminar        | Case study on industrial fermentation failure, contamination control, or scale-up of bioprocesses                    | Data collection/study = 5 hrs, Report preparation = 5 hrs Total = 10 hrs | Based on technical depth, problem analysis, and findings.                      |
| 10 | Other                                | Patent Search and Innovation Gap Identification in bioreactors, downstream processing, or fermentation technology    | 10 hrs (Search + Report)                                                 | Based on patent analysis and identification of research gaps/innovation scope. |

**Note:**

1. Mini Project – 10 Marks , Micro Project – 5 Marks
2. The hours allocated to specific activities should be proportionate to the total no. of PBL hours and marks.

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