

Uttarakhand Technical University

B.TECH (BIOTECHNOLOGY)

III YEAR, SEMESTER V

S.No.	Subject Code	Subject Title	Contact Hours / Week			Evaluation Scheme					Subject Total Marks
						Sessional Marks			ESE		
			L	T	P	CT	TA	Total	Marks	Duration (hrs)	
THEORY SUBJECTS											
1.	TBT501	Environmental Biotech	3	1	0	30	20	50	100	3	150
2.	TBT502	Enzymology	3	1	0	30	20	50	100	3	150
3.	TBT503	Cell and Tissue Culture	3	1	0	30	20	50	100	3	150
4.	TBT504	Genetic Engineering	3	1	0	30	20	50	100	3	150
5.	TBT505	Bioenergetics	2	1	0	15	10	25	50	3	75
6.	TBT506	Medical Biotechnology	2	1	0	15	10	25	50	2	75
PRACTICAL / DESIGN / DRAWING											
7.	PBT501	Environmental Biotech	0	0	3	10	15	25	25	2	50
8.	PBT502	Enzymology	0	0	3	10	15	25	25	2	50
9.	PBT503	Cell and Tissue Culture	0	0	3	10	15	25	25	2	50
10.	PBT504	Medical Biotechnology	0	0	3	10	15	25	25	2	50

TOTAL			15	5	9			350	600		950
11.	DIS 501*	Discipline	00	00	00	-	-	50			50
	TOTAL										1000

(* These marks will be awarded at the end of semester VI based upon the performances in both semester V & VI.)

CT- Cumulative Test

TA - Teacher's Assessment

ESE- End Semester Examination

ENVIRONMENTAL BIOTECHNOLOGY

TBT 501

Unit I

Introduction to Environment: Concept of ecology and ecosystem, environmental pollution (Water, soil and air) noise and thermal pollution, their sources and effects. Environmental laws and policies.

Unit II

Sewage and waste water treatments anaerobic and aerobic treatment, conventional and advanced treatment technology, methanogenesis, methanogenic, acetogenic, and fermentative bacteria-technical process and conditions, emerging biotechnological processes in waste – water treatment.

Unit III

Solid waste management: Landfills, composting, earthworm treatment, recycling and processing of organic residues. Biodegradation of xenobiotic compounds, organisms involved in degradation of chlorinated hydrocarbons, substituted simple aromatic compounds, polyaromatic hydrocarbons, pesticides, surfactants and microbial treatment of oil pollution.

Unit IV

Bioremediation and Biorestation: Reforestation through micropropagation, development of stress tolerant plants, use of mycorrhizae in reforestation, use of microbes for improving soil fertility, reforestation of soils contaminated with heavy metals.

Unit V

Environmental Biotechnology in Agriculture: Biofertilizers and microbial inoculants, biopesticide, bioinsecticides, bioherbicides Biofuel: Plant derived fuels, Energy crops, Biogas, Bioethanol, biohydrogen Environmental genetics: degradative plasmids, release of genetically engineered microbes in environment.

Text / Reference Books:

1. Environmental Biotechnology by Alan Scragg (1999); Longman.
2. An Introduction to Environmental Biotechnology by Milton Wainwright (1999): Kluwer Academic Press.

ENVIRONMENTAL BIOTECHNOLOGY

PBT 501

- 1.** Degradation of pesticide in soil and estimation of its residue.
- 2.** Determination of fluoride in water/soil/biosamples.
- 3.** Determination of LD₅₀ for common pesticides/weedicides.
- 4.** Bacteriological Analysis of wastewater.
- 5.** Demonstration of Biosensors, Principle & Application, eg. BOD, Nitrite, sulfite on the basis of availability.

ENZYMOLGY

TBT 502

Unit I

Introduction to enzymes: Brief history of enzymes, nomenclature and classification of enzymes. Chemical nature of Enzymes: amino acids, the building blocks of protein, Levels of protein Structure: Primary, secondary, tertiary and quaternary structure. Specificity of Enzymes: Types of specificity, the Koshland “induced fit” hypothesis, Strain or transition – state stabilization hypothesis.

Unit II

Enzyme Catalysis and Kinetics: Factors affecting the rate of chemical reactions, kinetics of uncatalyzed chemical reactions, kinetics of enzyme-catalyzed reaction, methods for investigating the kinetics of enzyme-catalyzed reactions, nature of enzyme catalysis, inhibition of enzyme activity.

Unit III

The Investigation of Active Site Structure and Chemical nature of Enzyme Catalysis: The identification of binding sites and catalytic site, three dimensional structure of active site, mechanism of catalysis, mechanism of reaction catalyzed by enzyme without cofactors, metal-activated enzyme and metalloenzyme, coenzymes in enzyme catalyzed reactions.

Unit IV

Immobilization of Enzymes: Concept, methods of immobilization, Kinetics of immobilized enzymes, effect of solute partition and diffusion on kinetics of immobilized enzymes, use of immobilized enzymes.

Unit V

Industrial uses of enzymes: Industrial enzymes: Sales value of industrial enzymes, traditional (non-recombinant) sources of industrial enzymes. Enzyme Engineering: Prediction of enzyme structure, design and construction of novel enzymes.

Text / Reference Books:

1. Enzymes by Palmer (2001): Horwood Publishing Series.
2. Fundamentals of Enzymology by Price and Stevens (2002): Oxford University Press.
3. Enzyme Technology by Helmut uhlung (1998): John Wiley
4. Introduction to Proteins Structure by Branden and Tooze (1998): Garland Publishing Group.

ENZYMولوجY
PBT 502

1. To prepare a sample of enzyme extract.
2. To determine activity of acid phosphatase from peas/moong seedlings.
3. Purification of an enzymatic protein by salt precipitation.
4. Determination of kinetic properties (K_m and V_{max} values) of an enzyme.
5. To check time and protein linearity of an enzymatic reaction.
6. To obtain standard curve of p-nitrophenol solution.
7. Immobilization of an enzyme.

CELL AND TISSUE CULTURE

TBT 503

Unit I

Historical background and terminology used cell & tissue culture. Basic techniques of cell and tissue culture, surface sterilization, aseptic tissue transfer, concept of totipotency. Nutritional requirement of cell *in vitro*, various types of nutrient media. Basic aseptic techniques.

Unit II

Physical Environment: Surface, PH Temperature. Chemical Environment – Properties of media, balanced salt solutions, Natural media, synthetic Media (with Serum & Serum free media), complex media. Primary Cell Culture: Disaggregation Techniques, Isolation, Propagation, Immortalization of cell lines, Routine maintenance.

Unit III

Somatic embryogenesis and organogenesis in plants. Variability in tissue cultures, somaclonal and other variations. Isolation of cells, single cell cultures and cloning. Zygotic embryo culture, Micropropagation and cloning of plants, applications of micro propagation in agriculture, horticulture & forestry.

Unit IV

Protoplast Isolation and culture, fusion of protoplast. Haploid Production: Introduction, Techniques, factors affecting embryogenesis, plant regeneration from poller embryo, gynogenesis diploidization to raise homozygous diploids applications, limitation.

Unit V

Contamination and cytotoxicity: Sources and types of microbial contamination, Monitoring: Viability assay, Survival assay and transformation assay. Preservation of cell lines: cryopreservation, cell banks, transporting cells. Somatic Hybridization: Fusogens, basis of somatic hybridization technology, storage of hybridoma cells, Productions of monoclonal antibodies. Large scale animal cell culture, culture Parameters, scale-up of anchorage-dependent cell, Suspension culture.

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Recommended Books:

1. Plant tissue culture: S.S. Bhojwani and M.K. Razdan, Elsevier Science, The Netherlands.
2. Cell culture methods and cell biology procedure: A. Doyle.
3. Plant Tissue Culture – A practical Approach: R.A. Dixon, IRL press.
4. Cell and Tissue Culture: Lab procedures in biotechnology, Alan Doyal (ed) J.Bryan Griffith (ed.)
5. Doods. J.H. & Roberts L.W. (1985). Experiments in plant tissue culture Cambridge Univ. Press.
6. Animal Cell Culture by John R.W. Masters.
7. Cell & Tissue Culture: Lab procedure in biotechnology alan Doxal(ed) J. Bryan scritith ed.
8. Animal or Animal cell & tissue culture techniques 5th freshness.

CELL AND TISSUE CULTURE
PBT 503

1. Tissue culture, media preparation-MS/White media, Slant preparation
2. Sterilization techniques
3. Culture of axillary meristems for clonal multiplication.
4. Embryo culture.
5. Artificial seeds.
6. Shoot tip culture.
7. Isolation of protoplasts.

GENETIC ENGINEERING

TBT 504

Unit I

Introduction and Tools for Genetic Engineering:

Introduction of RDT, Restriction enzymes, Modifying enzymes, DNA ligase, Polymerase etc. Cloning Vectors: Plasmids, Lambda phage, Phagemids, Cosmids, Artificial chromosomes (BACs, YACs), Shuttle vectors, virus based vectors.

Unit II

Gene Transfer Technology

Different methods of gene isolation, Techniques of DNA sequencing, Artificial DNA synthesis. Methods of gene transfer: Transformation, transduction, Particle gun, Electroporation, liposome mediated, microinjection, Agrobacterium mediated gene transfer.

Unit III

Polymerase Chain reaction (PCR) and applications:

Basic principles, modifications, applications. Gene libraries: cDNA synthesis, Genomic DNA libraries, Amplification of gene libraries, Identifying the products of cDNA clones.

Unit IV

Analysis and expression of cloned gene in host cells:

Expression vectors, Restriction enzyme analysis, Southern blotting, Northern blotting, Western blotting, In-situ hybridization. Colony and plaque hybridization, Factors affecting expression of cloned genes, Reporter genes, Fusion proteins.

Unit V

Application of recombinant DNA in biotechnology:

Antisense and ribozyme technology, Human genome project and its application, Gene therapy prospect and future, DNA vaccine, Transgenic plants.

Text/ References Books:

1. Recombinant DNA 2nd Edition. Watson, James D. and Gilman, M. (2001) W.H Freeman and Company, New York.
2. Molecular Biotechnology: *Principles Application of Recombinant DNA* 2nd Edition. Glick, B. R. and Pasternak, J. J. (1998) ASM press Washington DC.
3. Genetic Engineering. Ahluwalia, K. B. (2002) New Age International (P) Ltd.
4. An Introduction to Genetic Engineering 2nd edition Desmond Nicholl S.T. (2002) Cambridge University Press.

BIOENERGETICS

TBT 505

Unit I

Energy, energy flow cycle, energy conversion; Structure and properties of ATP; High energy compounds, Thermodynamic considerations, Coupling reactions of ATP and NDP (nucleotide di phosphate); photosynthesis.

Unit II

Biological membrane: structure, permeability, properties, passive transport and active transport, facilitated transport, energy requirement, mechanism of Na^+ / K^+ , glucose and amino acid transport.

Unit III

Metabolism and bioenergetics; Generation and utilization of ATP; Metabolism of Nitrogen containing compounds: nitrogen fixation, amino acids and nucleotides.

Unit IV

Energetics of Metabolic Pathways; Energy Coupling (ATP & NADH); Stoichiometry and energetic analysis of Cell Growth and Product Formation - elemental Balances, Degree of reduction concepts; available-electron balances; yield coefficients; Oxygen consumption and heat evolution in aerobic cultures; thermodynamic efficiency of growth.

UNIT-V

Electron Flow as source of ATP Energy, Site of Oxidative Phosphorylation, ATP synthetase, Electron- Transferring Reactions, Standard Oxidation, Electron Carrier, electron transport complexes, Incomplete reduction of Oxygen, Mechanism of Oxidative Phosphorylation, Oxidation of Extra mitochondrial NADH, ATP yield and P: O Ratio, Role of Electron Transport Energy, Respiratory Inhibitors, Regulatory control among Glycolysis, the Citric Acid Cycle and Oxidative Phosphorylation

Text books:

1. Introduction to Chemical Engineering thermodynamics by Smith and Vannes (Mcgraw Hill).
2. Chemical engineering thermodynamics by Y.V.C. Rao (New age international)

Reference books: 1. Engineering Thermodynamics by J.B.Hawkins (John Wiley Publication) 2. Engineering Thermodynamics by Spading and Cole (ELBS0).

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III YEAR, SEMESTER VI

S.No.	Subject Code	Subject Title	Contact Hours / Week			Evaluation Scheme					Subject Total Marks
						Sessional Marks			ESE		
			L	T	P	CT	TA	Total	Marks	Duration (hrs)	
THEORY SUBJECTS											
1	TBT601	Genomics & Proteomics	3	1	0	30	20	50	100	3	150
2	TBT602	Bioprocess Engineering	3	1	0	30	20	50	100	3	150
3	TBT603	IPR ,Bioethics and Biosafety	2	0	0	15	10	25	50	3	75
4	TBT604	Recent Advancements in Biotechnology	2	0	0	15	10	25	50	3	75
5	TBT605	Bioreactor analysis and design	3	1	0	30	20	50	100	3	150
6.	TBT606	Downstream Processing	3	1	0	30	20	50	100	3	150
PRACTICAL / DESIGN / DRAWING											
7.	PBT601	Genomics & Proteomics	0	0	3	10	15	25	25	2	50
8.	PBT602	Bioprocess Engineering	0	0	3	10	15	25	25	2	50
9.	PBT603	Recent Advancements in Biotechnology	0	0	3	10	15	25	25	2	50
10.	PBT604	Downstream Processing	0	0	3	10	15	25	25	2	50
11.	DIS 601*	Discipline	00	00	00	-	-	50			50

Grand Total	15	5	9	-	-	400	600	-	1000
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(* These marks will be awarded on the basis of performance of both semesters V & VI.)

(Note: The students will go for 4 weeks practical training in summer vacation after semester VI. The presentation & examination will be conducted in semester VII.)

CT- Cumulative Test

TA - Teacher's Assessment

ESE- End Semester Examination

GENOMICS AND PROTEOMICS

TBT 601

Unit I:

Introduction to Genomics

Genome evolution and phylogenetics Origin of genomes, Acquisition of new genes, DNA sequencing – chemical and enzymatic methods, The origins of introns, DNA and RNA fingerprinting, The human genome.

Unit II:

Structural and Functional Genomics

Technology, Sequences Comparison Techniques [BLAST], Genome, Annotation, ESTs, Digital Northern, SAGE, Relational Data Base Basics, cDNA Microarrays, Oligonucleotide Microarray Chips, Cancer and genomic microarrays, Application of Microarrays with examples, Microarray Data Analysis; Gene finding tools.

Unit III:

Introduction to proteomics

How to analyze a Proteome – 2D-gel electrophoresis, high-throughput proteome analysis with 2D-IEF, MALDI-TOF mass spectrometry

Unit IV:

Protein Structure and Function

Structure function relationship, Protein-protein interactions – Large molecular complexes – RNA polymerase II, ribosome; Unstructured proteins – Current concepts and examples, the fly-casting mechanism; Current Degradation Concept.

Unit V:

Application of Genomics and Proteomics

Genome sequencing projects (technology of sequencing and assembly, bioinformatics of genome annotation, current status of genome sequencing projects) Genomic browsers and databases. Study of Post translational Modifications: Methods of applications, Aspects of Clinical Proteomics; Protein micro arrays and MS Imaging

Recommended books:

1. Genomes II, T.A. Brown
2. Biotechnology and Genomics by P.K.Gupta
3. A Primer of Genome Science, Greg Gibson and Spencer V. Muse
4. Database Annotation in Molecular Biology : Principles and Practice, Arthur M. Lesk
5. DNA : Structure and Function, Richard R. Sinden
6. Recombinant DNA (Second Edition), James D. Watson and Mark Zoller
7. Gene Cloning and DNA Analysis – An introduction (Fourth Edition), T.A. Brown
8. Genes & Genomes, Maxine Singer and Paul Berg
9. Essential of Genomics and Bioinformatics, C.W. Sensen, John Wiley and Sons Inc.

GENOMICS AND PROTEOMICS LAB

PBT 601

1. To study DNA sequencing methods
2. To study gene finding tools and Genome annotation
3. To study comparison of two given genomes
4. To study the analysis of 2D – IEF data
5. To study Two-hybrid methods

BIOPROCESS ENGINEERING

TBT 602

Unit I

Microbial growth, Mass balance, Maintenance coefficient and yield concept, Volumetric mass transfer coefficient, Kinetics of Batch, Continuous and Fed-batch processes, isolation, preservation and maintenance of Industrial important microorganism.

Unit II

Bioreactors: components and control of process parameters , Types of bioreactors: CSTR, Airlift, Fluidized bed, plug flow reactor, Principle of microbial nutrition, formulation of culture media, selective media, factors influencing the choice of various carbon and nitrogen sources, vitamins, minerals, precursors and antifoam agents, importance of pH, fluid vs. solids, fluid static's mass and energy balance in fluid flow, Bernoulli's equation, flow past immersed bodies and drag coefficient. Sterilization of process fluids, recovering and purifying products, integration of reaction and separation.

Unit III

Downstream processing: Introduction, removal of microbial cells and solid matter, Foam separation, precipitation, filtration, centrifugation, cell disruption, liquid liquid extraction and Chromatography, recovery and purification of fermentation products, Up scaling of bioprocess

Unit IV

Diffusion and Mass Transfer: Biological production consideration, large scale production, Enzyme kinetics, cell growth, energetics and mass transfer. Production of Penicillin, Streptomycin, Tetracycline and other Antibiotics.

Unit V

Fermentative production, Organic solvents, acetone, ethanol, butanol, Organic acids: lactic acid, citric acid and acetic acid, Enzymes (Proteases, Lipases and alpha-amylase), Amino acids (L-glutamic acid, phenylalanine and L-lysine)

Recommended Books:

1. Biochemical Engineering: J.M. Lee, Prentice Hall.
2. Bioprocess Engineering: M. Shuler and F. Kargi, Pretice Hall.
3. Comprehensive Biotechnology: M. MooYoung, Editor.
4. Biotechnology: H.J. Rehm and G. Reed, VCH.

BIOPROCESS ENGINEERING LAB

PBT 602

1. Isolation of Pure culture
2. Maintenance of Pure culture
3. Preservation of Industrial important microorganism by different method
4. Amylase activity
5. Antibiotic production by Fungi
6. Wine production

INTELLECTUAL PROPERTY RIGHT, BIOETHICS AND BIOSAFETY

TBT 603

Unit I

General Patent Information: US patent laws, patentable subject matter. Requirements for patentability: Utility, Novelty, Nonobviousness, Sufficiency of disclosure. Rights of a patent, infringement of a patent. Procedures for obtaining patent protection. Types of patent applications : Provisional & regular Parts of patent applications.

Unit II

Patent prosecution, Appeals & interference proceedings. Applying for foreign patent protection. Unique aspects of Biotechnology patent laws & procedures: fulfillment of the Utility, Novelty, Nonobviousness, sufficiency of disclosure requirements. **WTO:** As an international agency controlling trade among nations. WTO with reference to biotechnological affairs, TRIPs

Unit III

Special issues in Biotechnology Patents Disclosure requirements, Collaborative research, Competitive research, Indian patents and Foreign patents, Plant variety protection act, The strategy of protecting plants. **Patent Litigation** Substantive aspects of patent litigation, Procedural aspects of patent litigation, different Doctrines.

Unit IV

Bioethics: Legality, morality and ethics, the principles of bioethics: autonomy, human rights, beneficence, privacy, justice, equity etc., The expanding scope of ethics from biomedical practice to biotechnology, ethical conflicts in biotechnology - interference with nature, fear of unknown, unequal distribution of risks and benefits of biotechnology, bioethics vs. business ethics, ethical dimensions of IPR, technology transfer and other global biotech issues.

Unit V

Biosafety concepts and issues: Rational vs. subjective perceptions of risks and benefits, relationship between risk, hazard, exposure and safeguards, biotechnology and biosafety concerns at the level of individuals, institutions, society, region, country and the world. Role of patent in pharmaceutical industry, computer related Innovations, Case **studies** Rice, Haldi, neem, etc. and challenges ahead

Text / Reference Books:

1. The law and strategy of Biotechnological patents by Sibley. Butterworth publications.
2. Intellectual property rights – Ganguli – Tata McGrawhill
3. Intellectual property right – Wattal – Oxford Publishing House.

RECENT ADVANCEMENTS IN BIOTECHNOLOGY

TBT 604

Unit I: Bioremediation

Introductory concept, Bioremediation principles, mechanism for Bioremediation of air, water and soil pollutants, bioremediation examples, commercial application of bioremediation techniques, recombinant DNA technology and bioremediation, bioremediation models, bioremediation software

Unit II: Genetically modified organisms

Genetically modified food crops, food animals – examples and mode of production, future goals in GM food crops and animals, scientific evaluation of public concerns, legal requirements in production of GMO, current trends and consumer acceptance.

Unit III: Molecular medicine

Gene mutation, point mutation, allele specific oligonucleotides, ARMS, oligonucleotide ligation, disease diagnosis with linked genetic markers, fluorescently labeled DNA sequencing.

Unit IV: Nano-biotechnology

Introduction, definition, hybrid nanoparticles, smart drug delivery, gene sensors, biomolecule control, nanofluids, nanotechnology in medicine.

Unit V : Stem cells technology

Definition, properties, proliferation, culture of stem cells, medical applications of stem cells, ethical and legal issues in use of stem cells.

References:

1. The Cell – A molecular Approach, 3rd Edn, Geoffrey M. Cooper and Robert E. Hausman, ASM Press
2. Molecular Biology and Biotechnology, 4th Edn, J.M Walker and R. Rapley, Panima Books
3. Cell Biology, David. E. Sadava, Panima Books, Stem Cell Biology, Daniel Marshak, Richard L. Gardener and David Gottlieb, Cold Spring Harbour Laboratory Press
4. Environmental Microbiology, 2nd Edition, Ian L .Pepper and Charles P. Gerba, Elsevier Pub.
5. Environmental Biotechnology – Concepts and Application, Hans – Joachim Jordening and Jesefwinter – Wiley – VCH

BIOREACTOR ANALYSIS AND DESIGN

TBT 605

Unit I

Bioreactor: Types of reactor: Batch, plug flow reactor (PFR), continuous stirred tank reactor (CSTR), Fluidized bed reactor, bubble column, air lift fermenter, mechanical design of bioreactors.

Unit II

Concept of ideal and non ideal reactors, residence time distribution, models of non ideal reactors – plug flow with axial dispersion, tanks-in-series model, chemostat model with cell growth kinetics.

Unit III

Plug flow reactor: For microbial processes, optimization of reactor systems. Multiphase bioreactors: Packed bed with immobilized enzymes or microbial cells, three phase fluidized bed trickling bed reactor, design and analysis of above reactor systems.

Unit IV

Unconventional bioreactors: Gas liquid reactors, hollow fiber reactor, membrane reactor and perfusion reactor for animal and plant cell culture

Unit V

High Performance Bio Reactors: Sterile and non sterile operations - Reactors in series with and without recycle. Design of Reactors. Reactors for Solid state fermentation.

Text/Reference Books:

1. Landfill Bioreactor Design & Operation. Reinhart Debra R, Townsend Timothy G. and Townsend Tim(1997) Lewis Publishers, Inc.
2. Multiphase Bioreactor Design. Edited by: Joaquim M.S. Cabral, Manuel Mota, Johannes Tramper (2001) CRC Press.
3. Bioreactor & Ex Situ Biological Treatment Technologies – 5. Allerman Bruce, Allerman Bruce C, Leeson Andrea, (1999). Battelle publisher.
4. Bioreaction Engineering: Modeling & Control. vol. I&II. Schugerl K, and Bellgardt K.H, (2000), Springer Verlag pub.

DOWNSTREAM PROCESSING

TBT 606

Unit I

Introduction: History and scope of downstream processing in biotechnology, problems, requirement of purification. Overview of a bioprocess including upstream and Downstream processing. Characteristics of biotechnology products, classes of bioproducts, physicochemical basis of bioseparation.

Unit II

Cell disintegration: Separation of particulate by filtration, centrifugation, settling, sedimentation, decanting and micro filtration. Primary isolation methods including solvent extraction, sorption, precipitation, ultra filtration and reverse osmosis.

Unit III

Purification methods: Fractional precipitation, electrophoresis, electro dialysis and various kinds of chromatography.

Unit IV

Emerging separation techniques: Dynamic immobilization, reverse osmosis, super critical fluid extraction evaporation, super liquid extraction and foam based separation. Separation of intracellular, extracellular, heat and photosensitive materials. Product recovery trains - a few examples.

Unit V

Downstream processes and effluent treatment: applications of Unit Operations in Downstream with special reference to membrane separations & extractive fermentation, anaerobic and aerobic treatment of effluents. Typical examples for downstream Processing and effluent disposal in process industries.

Text/Reference Books:

1. Biochemical Engineering fundamentals 2nd ed. Bailey J. E. and Ollis D. F. (1986) MacGraw Hill, New York.
2. Principles of fermentation technology, Stanbury, P. F. and Whitaker, A. (1984), Pergamon press.
3. Unit Operation of Chemical Engineering 6th ed. McCabe, W. L; Smith J. C and Harriott P. (2000). MacGraw Hill, New York
4. Separation Process Principles, Seader, J.D. & Henley, E.J. (1998) John Wiley & Sons, Oxford.
5. Bioseparation: Downstream Processing for Biotechnology. Belter, P. A.; Cussler E. L. and Hu W. S. (2003) John Wiley & Sons. OXFORD.
6. Bioseparations Science and Engineering, Harrison R.G.; Todd P.; Rudge S.R. and Petrides D.P. (2003). Oxford Press.
7. Wastewater Engineering 4th ed. Metcalf and Eddy (2002). MacGraw Hill, New York.

