Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT401	**Process Dynamics and Control**	**4-0-0**	**4**	**2016**

Prerequisite : Nil

Course Objectives:

- To provide an overview of the design elements of a control system.
- To study dynamics of a system for a specific input through the development of its transfer function.
- To identify control objectives, select measurements and manipulate variables, select control configuration and design a suitable controller.

Syllabus

Introduction to process control, process control strategies, general modeling principles, process control variables, model development and tools for solving models, Transfer functions and development of transfer functions, general characteristics of under damped, over damped and critically damped systems, hardware elements of a control system, dead time processes, dynamic behavior of feedback controlled processes, servo and regulatory responses, frequency response analysis of linear processes, stability analysis of feedback systems, design of feedback controllers, controller tuning, introduction to advanced controller designs.

Expected outcome

Upon successful completion of this course, a student will be able to

i. Explain relevant terms in conventional process control.
ii. Distinguish input/output variables in process control.
iii. Develop general mathematical model of a control system.
iv. Design simple stable conventional controllers.
v. Carry out stability analysis of feedback systems.

Reference Books:

1. Stephanopoulose G, *Chemical Process Control: An Introduction to Theory and Practice*, Prentice Hall of India, New Delhi, 1993.
2. Coughanowr R D, LeBlanc E S, *Process Systems Analysis and Control*, McGraw Hill International Edition.
3. Luyben W L, *Process Modeling Simulation and Control for Chemical Engineers*, 2/e, McGraw Hill, Singapore, 1990.
4. Seborg D E, Edgar TF, Mellichamp D A, Doyle FJ, *Process Dynamics and Control*,3/e, John Wiley& Sons, 2010.
5. Peter Harriot, *Process Control*, Tata McGraw Hill, 1972.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
	Introduction to process control with the help of examples of a tank heater system and a distillation column.	1	
	Hardware elements of a control system. Explanation with the help of an example of a tank heater system.	1	
	Transfer functions of measuring devices (sensors), transmission lines and final control elements (pneumatic control valves and control valve characteristics). Dead time processes.	1	

I	Transfer functions and their general characteristics. Analysis of dynamics of a system based on transfer function.	1	15%
	General modeling principles. Classification of variables in process control. Importance of state variables, state equations and degrees of freedom. Input-output models. Difficulties in modeling and additional elements of modeling.	1	
	Illustration of model development using an example of a tank heater system.	1	
	Tools for solving models: Laplace Transforms: Definition of Laplace transform. Laplace transforms of some basic forcing functions - step, exponential, ramp, sinusoidal, cosine, pulse, impulse and translated functions, Laplace transform of derivatives and integrals, initial value theorem and final value theorem.	2	
	Solution of linear differential equations using Laplace transforms. Inversion of Laplace transforms. Heaviside expansion.	2	
II	Transfer functions of SISO system. Transfer functions of a general first order and second order systems.	2	15%
	First order systems and its general characteristics. Development of transfer function models for first order systems: a continuous single tank (mass storage) system and a continuous single tank heater (energy storage) system. Dynamics of a first order system for step and ramp input.	2	
	Purely capacitive processes and non linear systems. Procedure of linearization with the help of examples of first order system with the presence of non linear valve and conical tank	2	
	Development of transfer function models for second order systems: multi capacity systems - two tanks connected in series, inherently second order systems - U tube manometer, damped vibrator, first order system in the presence of a controller. Dynamics of second order systems	2	
	General characteristics of under damped, over damped and critically damped systems. Numerical problem on overshoot, decay ratio, period of oscillation, ultimate value and maximum value.	2	
FIRST INTERNAL EXAM			
III	Process control strategies-feedback, feed forward and inferential. Overview of control system design - traditional and model based approach. The rationale for dynamic process models and model classification - theoretical, empirical and semi empirical models.	2	15%
	Types of feedback controllers. Control laws and transfer functions of P, PI and PID controllers.	2	
	Dynamic behaviour of feedback controlled processes. Difference between open loop and closed loop control system. Closed loop transfer function for feedback (positive and negative) processes.	2	

	Servo and regulatory responses due to the presence of proportional control, integral control, derivative control action and composite control on the response of a feedback controlled process.	3	
IV	Frequency response analysis of linear processes and Bode plots. Response of a first order system to a sinusoidal input and its graphical representation.	2	15%
	Frequency response characteristics of a general linear system, dead time process, pure capacitive process and their graphical representations.	2	
	Frequency response characteristics of feedback controllers-P, PI and PID and composite controllers and their graphical representations.	2	
	Frequency response characteristics of second order systems and graphical representation frequency response characteristics of multi capacity systems.	1	
	Nyquist plots of first order, dead time and pure capacitive processes.	1	
SECOND INTERNAL EXAM			
V	Development of Bode plot for closed loop control systems. Cross over frequency, Gain and Phase margin.	2	20%
	Stability analysis of feedback systems: Notion of stability, Stable and unstable systems, BIBO stability, Prediction of stability of transfer function for open loop and closed loop systems based on transfer function analysis.	2	
	The characteristic equation, Routh Hurwitz criterion for stability, Numerical examples.	2	
	Root locus analysis. Rules for plotting Root locus Development of Root locus for multi capacity systems, Numerical Examples.	2	
	Bode stability criterion, Nyquist stability criterion	1	
VI	Design of feedback controllers: Outline of the design problems, simple performance criteria, time-integral performance criteria, selection of the type of feedback controller	2	20%
	Controller tuning: Controller tuning based on ¼ decay ratio, frequency response techniques, empirical tuning techniques - CC and ZN	2	
	Numerical examples of controller tuning based on ZN, CC, GM and PM and Bode Stability criterion	2	
	Advanced control system-Introduction to dead time compensation, adaptive controllers, cascade controllers, inverse controllers, feed forward controllers	2	
	State space models for a first and second order systems	2	
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT403	Bioinformatics	3-0-0	3	2016

Prerequisite: Nil

Course Objectives

- To introduce the fundamentals of evolution, molecular biology, molecular evolution and computational biology.
- To provide the bioinformatics concepts with emphasis on common bioinformatics tools and databases.
- To train in the basic theory and application of programs used for database searching, protein and DNA sequence analysis, prediction of protein function, and building phylogenetic trees.

Syllabus

Introduction to computers and Bioinformatics, Basic biomolecular concepts, Types of Nucleotide Sequence and DNA sequencing methods, Bioinformatics Resources, Sequence databases, Sequence file formats, Sequence Analysis, Sequence alignment.

Expected outcome

Upon successful completion of this course the student will be able to

i. Explain applications of Bioinformatics.
ii. Explain common bioinformatics tools.
iii. Explain nucleic acid sequence databases.
iv. Explain the basic concepts of sequence similarity.
v. Explain basic concepts of sequence alignment.

Reference Books

1. Teresa K Attwood, David J Parry-Smith, *Introduction to bioinformatics*, Pearson Education. 1999
2. Jean-Michel Claverie, Cedric Notredame, Bioinformatics *for Dummies*, Wiley Publishing Inc., 2007.
3. D W Mount, *Bioinformatics: Sequence and Genome Analysis*, 2/e, Cold Spring Harbor Laboratory, Press, New York. 2004.
4. Baxevanis A D, Francis Ouellellette B F, *Bioinformatics- a Practical Guide to the Analysis of Genes and Proteins*, Wiley Interscience, 2009.
5. David Edwards, Jason Stajich, David Hansen, *Bioinformatics Tools and Applications*, Springer, New York, 2009.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Aim and branches of Bioinformatics, Applications of Bioinformatics, Role of internet and World Wide Web in bioinformatics. Protein and amino acid, DNA & RNA, Sequence, structure and function. Forms of biological information.	5	15%
II	NCBI, EBI, ExPASy, RCSB, DDBJ, knowledge of databases and bioinformatics tools available at these resources, database organization, data contents, purpose and utility. PubMed, BioMed Central, Public Library of Sciences (PloS), CiteXplore.	6	15%
FIRST INTERNAL EXAM			

III	Genomic DNA, Complementary DNA (cDNA), Recombinant DNA (rDNA), Expressed sequence tags (ESTs), Genomic survey sequences (GSSs). Basic and Automated DNA sequencing, DNA sequencing by capillary array and electrophoresis, Gene expression data.	7	15%
IV	Nucleic acid sequence databases - GenBank, EMBL, DDBJ; Protein sequence databases – Uniprot, SWISS-PROT, TrEMBL, UniParc; Structure Databases: PDB, NDB, PubChem, ChemBank. GenBank, FASTA, GCG, MSF, Proteomics tools at the ExPASy server, GCG utilities and EMBOSS, Computation of various parameters.	8	15%
SECOND INTERNAL EXAM			
V	Basic concepts of sequence similarity, identity and homology, definitions of homologues, orthologues, paralogues and xenologues, Basic concept of a scoring matrix, Matrices for nucleic acid and proteins sequences, PAM and BLOSUM series, matrix derivation methods and principles.	8	20%
VI	Measurement of sequence similarity; Similarity and homology. Pairwise sequence alignment: Basic concepts of sequence alignment, Needleman and Wunsch, Smith and Waterman algorithms for pair-wise alignments, gap penalties, use of pair-wise alignments for analysis of Nucleic acid and protein sequences and interpretation of results.	8	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT405	Environmental Engineering	3-0-0	3	2016

Course Objectives

- To introduce science and engineering of air, water and solid pollution prevention.
- To expose environmental issues and problems, relevant environmental legislation and regulation and waste minimisation strategies.

Syllabus

Environmental legislation and regulation, water treatment methods, wastewater sampling and analysis, aerobic and anaerobic biological water treatment processes, sources, classification and management of solid wastes, effects of air pollution and air pollution control methods.

Expected outcome

Students who successfully completes this course should be able to

i. Explain water treatment methods.
ii. Explain sources and classification of wastewater.
iii. Describe common methods of wastewater treatment.
iv. Explain aerobic and anaerobic biological processes.
v. Explain the working of a sanitary landfill.
vi. Know the types of air pollutants and their control.

Reference Books

1. Mackenzie Leo Davis, Susan J Masten, *Principles of Environmental Engineering and Science*, McGraw-Hill Higher Education, 2004.
2. Metcalf and Eddy, *Wastewater Engineering, Treatment and Reuse*, Tata McGraw Hill, New Delhi, 2003.
3. C S Rao, *Environmental Pollution Control Engineering*, New Age International, 2007.
4. W W Nazaroff, Lisa Alvarez-Cohen, *Environmental Engineering Science*, Wiley, 2001.
5. Sawyer C N, McCarty P L, Parkin G F, *Chemistry for Environmental Engineering*, Tata McGraw-Hill, New Delhi, 2003.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Introduction to environmental engineering. Environmental legislation and regulation. Water treatment. Precipitation processes. Alum treatment and lime soda softening. Municipal water conditioning. Ion-exchange processes. Boiler feed water treatment. Reverse osmosis. Desalination. Membrane water purification. Nanotechnology for water purification.	6	15%
II	Sources and classification of wastewater. Physical, chemical and biological classification of wastewater. Types of water pollutants and their effects. Water quality standards. Wastewater sampling and analysis. Determination of organic matter. Dissolved oxygen. Biochemical oxygen demand, Chemical oxygen demand. Wastewater microbiology.	6	15%
FIRST INTERNAL EXAM			
III	Wastewater treatment methods. Pretreatment, Primary	7	15%

	treatment, Secondary treatment, Tertiary treatment, Screening, grit removal, oil removal, Equalisation, Neutralisation, Coagulation, Flocculation, and Sedimentation, Clarifiers and clariflocculation.		
IV	Aerobic and anaerobic biological processes. Design of activated sludge process. Trickling filters. Rotating biological contactors. Aerobic fluidized bed bioreactors. Anaerobic digestion process. Anaerobic fluidized bed bioreactors, Design of upflow anaerobic sludge blanket (UASB) reactor. Sand filters, pressure filtration, Sludge treatment and disposal. Disinfection.	8	15%
SECOND INTERNAL EXAM			
V	Solid waste, sources and classification. Sanitary landfill, Incineration, Composting-vermi, aerobic and anaerobic. Treatment of industrial waste from pulp and paper mill, textile mill, distillery and dairy industry and fermentation industries. Treatment of biomedical wastes.	7	20%
VI	Air pollution. Sources and classification of air pollution. Effects of air pollution, Air pollution control methods and equipment like settling chambers, cyclone separators, fabric filters, wet scrubbers, noise pollution, noise control methods, Recycling and reuse of wastes, waste minimization, Zero waste strategies, Hazardous waste management.	8	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

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Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT407	**Bioenergy Engineering**	**3-0-0**	**3**	**2016**

Prerequisite : Nil

Course Objectives

- To provide the basic principles of biologically-based processes for energy production.
- To impart fundamental principles, review of the state of the art, design and economics, and future perspectives of current and emerging biologically-based processes for energy production.

Syllabus

Introduction to bioenergy, Bioethanol - feedstock, yield and yield improvements, process design of a typical bioethanol plant, Biohydrogen - biohydrogen production processes and methods to improve efficiency, Biomethane and biogas, microbial fuel cells, microbial electrolysis cells, other bioelectrical systems, Life cycle analysis and sustainability of bioenergy systems an case studies.

Expected outcome

Upon successful completion the students should be able to

i. Describe global and national bioenergy policies and initiatives.
ii. Identify renewable feedstock for bioenergy production.
iii. Describe bioethanol, biomethane and biogas production processes.
iv. Describe working of microbial fuel cells and other bioelectrical systems.
v. Understand social, environmental and economic impacts biofuels.

Reference Books

1. Caye Drapcho, John Nghiem, Terry Walker, *Biofuels Engineering Process Technology*, McGraw-Hill, 2008.
2. Sunggyu Lee, Y.T. Shah, *Biofuels and Bioenergy: Processes and Technologies*, CRC Press, 2013
3. Shang-Tian Yang, Hesham El-Ensashy, Nuttha Thongchul, *Bioprocessing Technologies in Biorefinery for Sustainable Production of Fuels, Chemicals and Polymers*. John Wiley & Sons, 2013.
4. Samir K Khanal, *Anaerobic Biotechnology for Bioenergy Production: Principles and Applications*. Wiley-Blackwell, 2008.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	**Introduction to bioenergy** - bioenergy policies and initiatives (global and national), energy perspective, various renewable feedstock for bioenergy production, their availability and characteristics, energy yields from conversion of energy crops to biofuels:, energy content of biofuels, challenges in applying sustainable bioenergy systems and their further development.	7	15%
II	**Bioethanol** - basic principles, biological kinetics and yields, yield improvements, process design of a bioethanol plant, feedstocks, crop improvements, high value-added co-products and downstream processes for product recovery, state of the art and emerging applications, prospects and challenges, life cycle analysis and environmental implications.	7	15%

FIRST INTERNAL EXAM			
III	**Biohydrogen** - prospects of biohydrogen as a potential energy resource, basic principles, various biohydrogen production processes, dark and photofermentation, biological kinetics and yields - strategies to improve process efficiency, major challenges, cell engineering and emerging applications - design, life cycle analysis and environmental implications.	7	15%
IV	**Biomethane** and Biogas as high value renewable energy sources - properties, advantages and disadvantages, feedstocks and production processes, yields and yield improvements, methane production in landfills and its capture, Biogas digesters- design features and working principle.	7	15%
SECOND INTERNAL EXAM			
V	**Bioelectrical systems** - microbial fuel cells, microbial electrolysis cells, other bioelectrical systems-basic principles, state of the art processes, efficiency enhancement, design, life cycle analysis and environmental implications, emerging bioelectrical systems.	8	20%
VI	**Life cycle analysis and sustainability** of bioenergy systems, social, environmental and economic impacts biofuels, feedstock costs, capital costs, operating costs, food vs. fuel debate, Case studies of Hydrogen, Ethanol, and Biodiesel Production.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

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Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT409	Environmental Biotechnology	3-0-0	3	2016

Prerequisite: Nil

Course Objectives

- To introduce scientific aspects of biochemical and cellular processes in the removal and detoxification of environmental pollutants.
-

Syllabus

Microbes and metabolism, stoichiometry and energetics, important energy reaction, oxygen demand and its determination, biofilm-based processes, removal and detoxification of hazardous chemicals.

Expected outcome

Upon successful completion the students will be able to

i. Role of microorganisms in preventing and abating environmental pollution.
ii. Explain the common pathways in removal and detoxification of pollutants.
iii. Explain important energy reactions in waste degradation.
iv. Explain the source of BOD in wastewater and its determination.
v. Explain different types of biofilm processes.

Reference Books

1. Bruce E Rittmann, Perry L McCarty, *Environmental Biotechnology: Principles and applications*, McGraw-Hill, 2001.
2. Alan Scragg, *Environmental Biotechnology*, Oxford University Press, 2005.
3. Gareth M Evans, Judith C Furlong, *Environmental Biotechnology-Theory and Applications*, John Wiley & Sons, 2003.
4. T Srinivas, *Environmental Biotechnology*, New Age International,
5. P R Yadav, Rajiv Tyagi, *Environmental Biotechnology*, Discovery Publishing House, 2006.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Microbes-eukaryotes, prokaryotes, viruses and their role in environmental biotechnology, reproduction and growth, energy and carbon-source classes of bacteria, environmental conditions for growth, other multicellular organisms relevant to environmental biotechnology, functional diversity of microbes in natural environment, indicator microorganisms, detection of indicator microorganisms.	7	15%
II	Metabolism-description of biological macromolecules-lipids, carbohydrates, nucleic acids and proteins, metabolic pathways with particular relevance to environmental biotechnology, fermentation and respiration, electron and energy carriers, electron transport systems and oxidative phosphorylation.	6	15%
FIRST INTERNAL EXAM			

III	Stoichiometry and bacterial energetics-empirical formula for cells, substrate partitioning and cellular yield, important energy reaction-aerobic oxidation, denitrification, sulphate reduction, methanogenesis and ethanol fermentation, simple fermentation reactions, reactions of photosynthesis and phototrophic energy transfer reactions, overall reactions for biological growth.	8	15%
IV	Oxygen demand: Biochemical, Chemical, and Theoretical, oxygen demand, carbonaceous biochemical oxygen demand (CBOD), and nitrogenous BOD (NBOD), BOD curve, sources of BOD, Theoretical Oxygen Demand, BOD removal kinetics, CBOD rate coefficient, BOD measurement, application, and limitations, BOD Test: limitations and alternatives, seeding, dissolved oxygen sag curve, Numerical problems on BOD.	7	15%
SECOND INTERNAL EXAM			
V	Aerobic biofilm processes-basic principle, classification of biofilm processes, formation, structure and behaviour of biofilms, oxygen transport in biofilms, biofilm kinetics, fixed bed reactors, expanded bed reactors-fluidised-bed and circulating-bed biofilm reactors, advantages of biofilm reactors, hybrid biofilms/suspended growth systems, microbial mats.	8	20%
VI	Detoxification of hazardous chemicals- Degradation of highly concentrated toxic pollutants: Halogenated, Non halogenated & petroleum hydrocarbons, Mechanisms of detoxification-oxidation, dehalogenation, biotransformation of metals, use of genetically engineered organisms in removal and detoxification of hazardous chemicals, advantages and constrains in the use of genetically engineered organisms.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

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Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT461	Design of Biological Wastewater Treatment Systems	3-0-0	3	2016

Prerequisite : Nil

Course Objectives

- To provide the necessary theoretical background for the design of most common biological waste treatment systems.

Syllabus

Characteristics and *impacts of wastewater on* the environment, basic design considerations, types of biological treatment processes and reactors, aerobic suspended growth systems, anaerobic digesters, design consideration for upflow anaerobic sludge blanket reactors, biogas production.

Expected outcome

A student who successfully completes this course will be able to

i. Explain the characteristics of wastewater.
ii. Identify different types of reactors for wastewater treatment.
iii. Design a completely mixed activated sludge system.
iv. Explain the design features of an upflow anaerobic sludge blanket reactor.
v. Explain the factors affecting biogas production.

Reference Books

1. G Karia, R A Christian, *Wastewater Treatment: Concepts and Design Approach*, 2/e, PHI Learning Pvt., Ltd., 2013.
2. P Venugopala Rao, *Textbook of Environmental Engineering*, Prentice-Hall of India Pvt. Ltd., 2002.
3. Metcalf & Eddy, *Wastewater Engineering: Treatment and Reuse*, 4/e, Tata McGraw-Hill Education, 2003.
4. M Narayana Rao, Amal K Datta, *Waste Water Treatment: Rational Methods of Design and Industrial Practices*, 3/e, Oxford & IBH Publishing Company Pvt. Ltd., New Delhi,
5. R S Khoiyangbam, Navindu Gupta, Sushil Kumar, *Biogas Technology: Towards Sustainable Development*, The Energy and Resources Institute (TERI), 2011.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Wastewater-origin, characteristics, *impacts of wastewater on* the environment, basic design considerations-estimation of wastewater quantities, variation in wastewater flow rates-average daily flow, maximum daily flow, peak hourly flow, minimum daily flow, minimum hourly flow, process flow sheet, reactor considerations.	5	15%
II	Objectives and fundamentals of biological treatment, types of biological treatment processes, types of reactors used for wastewater treatment process, kinetics of biological treatment systems-batch and continuous systems, biological nitrogen removal, biological phosphorous removal.	5	15%
FIRST INTERNAL EXAM			

III	Aerobic suspended growth systems-Conventional activated sludge processes and its modifications-theoretical principles, design of completely mixed activated sludge system, F/M ratio, hydraulic loading, MLSS, MLVSS, sludge age, sludge return, calculation of the reactor volume, production and removal of excess sludge, sludge volume index, Solids Retention Time (SRT) or Mean Cell Residence Time, oxygen requirements.	8	15%
IV	Aerobic attached growth system-Trickling filters-theoretical principles, classification, design principles, process design considerations, Oxidation ponds-construction and design considerations, aerobic sludge digestion, waste stabilization ponds, oxidation ditches-theory and design, factors affecting the design, theory and design of rotating biological contactors	8	15%
SECOND INTERNAL EXAM			
V	Fundamentals of anaerobic treatment, types of anaerobic digesters-conventional systems, high-rate systems and combined treatment systems, design of upflow anaerobic sludge blanket reactors, anaerobic sequencing batch reactor, anaerobic filters-upflow and downflow anaerobic filters, sludge treatment and disposal, sludge digestion, sludge drying, sludge conditioning, sludge drying characteristics.	8	20%
VI	Biogas technology-microbiology of biogas production, process parameters for a biogas plant, biogas yield from different substrates, methods to enhance biogas production-effect of heating, insulation and stirring on gas production, basic components of a biogas plant, biogas plant designs-continuous type plants, semi-continuous plants, fixed dome type, floating gasholder digester (KVIC),kinetic models for predicting biogas production, design equations of biogas plants.	8	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

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Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT463	Bioprocess Optimization Modelling and Simulation	3-0-0	3	2016

Prerequisite : Nil

Course Objectives

- To introduce students to the fundamentals of mathematical modelling and its usefulness in optimizing and controlling bioprocesses.

Syllabus

Modelling principles, Formulation of balance equations, Information for bioreactor modelling and biological kinetics, Bioreactor modelling.

Expected outcome

A student who successfully completes this course will be able to

i. Importance of modelling bioprocesses.
ii. Explain different types of models used in optimising and controlling bioprocesses.
iii. Develop model equations for batch, chemostat, fed-batch reactor and plug flow reactors.
iv. Estimate model parameters and determine parameter sensitivity.
v. Understand the basic features of common simulation softwares.

Reference Books

1. J Mikles, M Fikar, *Process Modelling, Identification*, and Control, Springer, 2007.
2. Tapobrata Panda, *Bioreactors: Analysis and Design*, Tata McGraw-Hill Education, 2011.
3. I J Dunn, E Heinzle, J Ingham, J E P Fenosil, *Biological Reaction Engineering: Dynamic Modelling Fundamentals with Simulation Examples*, WILEY-VCH Verlag GmbH & Co., 2003.
4. W L Luyben, *Process Modeling, Simulation & Control for Chemical Engineers*, 2/e, McGraw-Hill, 1990.
5. Carl-Fredrik Mandenius, Nigel J Titchener-Hooker, *Measurement, Monitoring, Modelling and Control of Bioprocesses*, Springer, 2013
6. J M Douglas, *Conceptual Design of Chemical Processes*, McGraw- Hill Book Company, New York, 1988.
7. J R Leigh, *Modeling and Control of fermentation Processes*, Peter Peregrinus, London, Revised edition, 2000.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Modelling of bioprocesses-definition and use of models, importance of mathematical modelling, classification of models with example-theoretical models, empirical models, semi-empirical models, lumped and distributed parameter models, modelling principles, steps in model building, mathematical representation of bioprocess.	7	15%
II	Models for cell kinetics-structured, unstructured, segregated and unsegregated models, Monod and Leudeking-Piret models, state variables (cell growth, substrate consumption or product formation), intracellular physiological state markers and its use in the formulation of model, development of compartment and metabolic pathway models for intracellular state estimation.	6	15%

FIRST INTERNAL EXAM			
III	General mass balances for batch fermenter, chemostat, fed-batch reactor, tubular plug flow reactors, steady-state and unsteady-state balancing for tubular bioreactors, Models for oxygen transfer in large scale bioreactors: Oxygen gradient in a bubble column bioreactor, oxygen gradient in multiple impeller fermenters, modelling batch growth with oxygen limitation, modelling continuous flow stirred tank bioreactor with oxygen limited growth.	7	15%
IV	Parameter estimation, parameter sensitivity analysis, numerical integration techniques, statistical validity, dynamic simulation of batch, fed-batch steady and transient culture, numerical optimization of bioprocesses using mathematical models, optimisation criteria, model fitting and validation.	7	15%
SECOND INTERNAL EXAM			
V	Simulation Approaches-Sequential modular approach-Equation solving approach - Decomposition of networks, Typical examples. Flow sheet presentation, Block diagrams, Pictorial representation, Utilities, Manual & Computer aided flow sheeting, split fraction concept. Introduction to software packages for simulation of bioprocesses-MATLAB,SIMULINK and their essential features, simulation of bioprocesses using models from literature sources.	8	20%
VI	Simulation techniques: continuous system simulators, dynamic process simulators, steady state material and energy balance programs, Programs based on numerical methods like algebraic equations, Newton Raphson method for algebraic convergence, interpolation, arbitrary function generation. Programs based on solution of differential equations: Euler method for 1st and 2nd order integration.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

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Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT465	**Advanced Separation Processes**	**3-0-0**	**3**	**2016**

Prerequisite : Nil

Course Objectives

- To introduce students to modern/advanced separation process technologies not covered in traditional mass transfer and separation processes.

Syllabus

Classification of membrane separation processes, major areas of application, membrane modules, membrane materials, membrane separation models, non-conventional separation processes, chromatography and crystallisation.

Expected outcome

A student who successfully completes this course should be able to

i. Distinguish various membrane separation processes.
ii. Explain common membrane materials and their characteristics.
iii. Explain fouling, cleaning and regeneration of membranes.
iv. Explain the principle, applications of non- conventional separation processes.
v. Differentiate between various chromatographic techniques.

Reference Books

1. Kaushik Nath, *Membrane Separation Processes*, PHI Learning Pvt. Ltd,
2. Marcel Mulder, *Basic Principles of Membrane Technology*, 2/e, Kluwer Academic Publishers, 1996.
3. Richard W Baker, *Membrane Technology and Applications*, John Wiley & Sons Ltd, 2004.
4. Seader J D, Ernest J Henley, *Separation Process Principles*, Wiley New York, 1998.
5. Phillip C Wankat, *Separation Process Engineering*, 2/e, Pearson Education, 2007.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Membrane separation-classification of membrane separation processes-ultrafiltration, microfiltration, nanofiltration, reverse osmosis, dialysis, electrodialysis, pervaporation, advantages and disadvantages, major areas of application, choice of membranes, membrane modules-plate and frame, tubular, spiral wound, hollow fibre and capillary module, and their relative merits and demerits.	7	15%
II	Membrane materials, structure, and preparation techniques-ceramic membrane, polymeric membrane, composite membrane, liquid membrane, biological membranes, characteristics of membrane pore structures-pore size, pore size distribution, pore density and surface roughness, permeability and membrane resistance, controlling pore size and pore size distribution of membrane during preparation.	7	15%
FIRST INTERNAL EXAM			

III	Transport in membranes-driving forces for transport mechanisms, transmembrane flux, retention factor or separation factor, selectivity, factors affecting retentivity, concentration polarization, gel polarization, fouling, cleaning and regeneration of membranes, turbulence enhancers, membrane separation models-Irreversible thermodynamics, Capillary flow theory, Solution diffusion model, Viscous flow models.	7	15%
IV	Non-conventional separation processes-Principle, applications, advantages and disadvantages of Azeotropic and Extractive distillation, Reactive distillation, Membrane distillation, Reactive extraction, Separation using surfactants, Cloud point extraction, Supercritical fluid extraction, Field Flow Fractionation/Gradient Separation, Pressure swing adsorption.	7	15%
SECOND INTERNAL EXAM			
V	Elution Chromatography-Principles, retention theory, Principle and applications of Ion exchange chromatography, Affinity chromatography, Hydrophobic interaction chromatography, Gel filtration chromatography, Membrane chromatography, Affinity monolith chromatography, supercritical fluid chromatography, gas chromatography, chiral chromatography.	7	20%
VI	Crystallisation-solubility and saturation, mechanism of crystallisation, primary and secondary nucleation, crystal growth, diffusion-integration theory of crystal growth, the delta L law, size-dependent growth and growth dispersion, batch and continuous crystallisation equipments, Caking of crystals and its prevention.	7	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.

Course Code	Course Name	L-T-P	Credits	Year of Introduction
BT467	Biopharmaceutical Technology	3-0-0	3	2016

Prerequisite : Nil

Course Objectives

- To give an insight into various biopharmaceutical products, therapeutics and clinical uses, understand the dynamics of drug absorption, distribution and metabolism, conventional drug development process and regulatory procedures and production of selected biopharmaceutical products.

Syllabus

Various categories of biopharmaceuticals and their therapeutic and clinical uses, drug absorption, distribution, metabolism and elimination (ADME), bioavailability and bioequivalence of drugs, pharmacokinetic models and their applications, drug development, pre-clinical trials and clinical trials, regulations and manufacturing process, manufacture of selected biopharmaceutical products, stabilisation of biopharmaceutical products and finished product formulations, preservation of drugs.

Expected outcome

A student who successfully completes this course will be able to

i. Identify various categories of biopharmaceuticals and their uses.
ii. Explain the process of drug absorption, distribution, metabolism and elimination.
iii. Elucidate the importance of bioavailability and bioequivalence of drugs.
iv. Explain the approaches to drug discovery and development.
v. Describe the production of selected biopharmaceutical products

Reference

1. Gary Walsh, *Pharmaceutical Biotechnology: Concepts and Applications*, John Wiley & Sons, 2007.
2. C Kokate, SS Jalalpure, H J Pramod, *Textbook of Pharmaceutical Biotechnology*, Elsevier, 2011.
3. Joseph D. Nally, *Good Manufacturing Practices for Pharmaceuticals*, CRC Press, 2013.
4. Leon Lachman, Herbert A Lieberman, Joseph L. Kanig, *Theory & Practice of Industrial Pharmacy*, 4/e, CBS Publishers, 2013.
5. Heinrich Klefenz, *Industrial Pharmaceutical Biotechnology*, John Wiley, 2002.

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Introduction to pharmaceutical products, sources of biopharmaceuticals and pharmaceutical biotechnology, development of pharmaceutical industry in India, current and future status of biopharmaceutical sector-case studies, leading Indian pharma companies.	5	15%
II	Biopharmaceutical therapeutics and clinical uses-various categories of therapeutics (description and uses only): Cytokines – interferon, interleukins, tumour necrosis factor, heamopoietic growth factors-colony stimulating factor (granulocyte, macrophage), erythropoietin. Hormones – insulin, antibodies, Oligonucleotides, oligosaccharides,	6	15%

	glycoproteins, bacterial vaccines, cardiovascular drugs, hematopoietic agents. Anticoagulants, anthrombotics and hemostatics. Chemotherapeutic Agents, Endocrine Drugs.		
FIRST INTERNAL EXAM			
III	Dynamics of drug absorption, distribution, metabolism (Biotransformation - phase I, II reactions), and elimination (ADME), bioavailability of drugs, Bioequivalence its importance and determination, physicochemical factors affecting all the above, mechanism of drug action, drug receptors, physiological receptors: structural and functional families, plasma drug concentration - time profile.	9	15%
IV	Pharmacokinetic models and their applications- one, two and multiple compartment models, non-compartment models and physiologic models, applications and limitation of physiologic pharmacokinetic models, mean residence time (MRT), statistical moments theory, mean absorption time (MAT), mean dissolution time (MDT), non-linear kinetics.	9	15%
SECOND INTERNAL EXAM			
V	Drug Discovery and drug development: sources of drugs - plant, animals, microbes and minerals, conventional drug development process-drug discovery, pre-clinical trials, clinical trials, regulatory procedures, approval. Role of FDA, Important amendments in drugs regulation. Indian drugs and cosmetic act. Economics of drug industry.	6	20%
VI	Biopharmaceuticals-an industrial perspective: International pharmacopeia, guide to good manufacturing practice, manufacturing facility. Production of selected biopharmaceutical products-Therapeutic Proteins, Hormones, Interferons, Interleukins I & II, Tumor Necrosis Factor, antibiotics, Nucleic acids. Stabilisation of biopharmaceutical products and finished product formulations, excipients, Preservation of drugs, Packing of drugs	8	20%
END SEMESTER EXAMINATION			

QUESTION PAPER PATTERN:

Maximum Marks: 100 Exam Duration: 3 hours

The question paper consists of Part A, Part B and Part C.

Part A consists of three questions of 15 marks each uniformly covering Modules I and II. The student has to answer two questions (15×2=30 marks).

Part B consists of three questions of 15 marks each uniformly covering Modules III and IV. The student has to answer two questions (15×2=30 marks).

Part C consists of three questions of 20 marks each uniformly covering Modules V and VI. The student has to answer two questions (20×2=40 marks).

For each question there can be a maximum of 4 subparts.